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Public Health Service
Washington, D. C.

December 1964

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service • Division of Radiological Health

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Section I—Air and Fallout

FISSION PRODUCT BETA ACTIVITY IN AIRBORNE PARTICULATES AND PRECIPITATION

Continuous surveillance of gross beta activity in air and precipitation provides one of the earliest and most sensitive indications of changes in environmental fission product activity. Although this surveillance does not provide enough information to assess human radiation exposure from fallout, it is widely used as the basis of alerting systems for determining when to intensify monitoring in other phases of the environment.

Surveillance data from a number of national programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. Data provided by programs of the Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization are presented individually in tabular form and are also shown by beta concentration isograms in figure 6.

1. Radiation Surveillance Network
June 1964

Division of Radiological Health,
Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Surveillance Network (RSN) of the PHS Division of Radiological Health which gathers samples from 74 stations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The alerting function of the network is provided by field estimates of the gross beta activity of airborne particulates on the filters. These determinations are performed about 5 hours after the end of the sampling period to allow for decay of naturally-occurring radon daughters. The network station operators regularly report their field estimates to the Radiation Surveillance Center, Division of Radiological Health, Washington, D. C. These field estimates are reported elsewhere on a monthly basis (*1*). When unusually high air levels are reported, appropriate Federal and State officials are promptly notified.

Air

Airborne particulates are collected continuously on a carbon-loaded cellulose dust filter 4 inches in diameter. A volume of about 1800 cubic meters of air is drawn through the filter during the 24-hour sampling period by a high volume centrifugal blower.

The filters are forwarded to the Radiation Surveillance Network laboratory in Rockville, Maryland, where the gross beta activity is measured using a thin-window, gas-flow proportional counter, calibrated with a Sr^{90}–Y^{90} standard. Each filter is counted at least 3 days

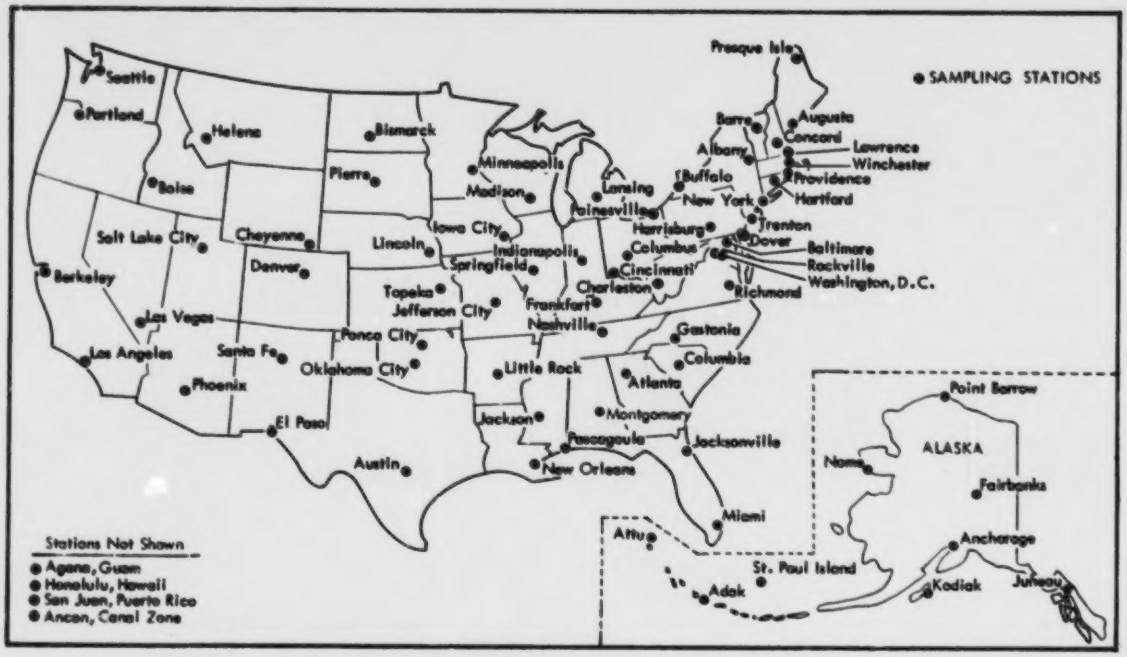
SAMPLING STATIONS
Seattle
Portland
Helena
Bismarck
Boise
Pierre
Minneapolis
Madison
Lansing
Painesville
Buffalo
New York
Presque Isle
Barre
Augusta
Concord
Albany
Lawrence
Winchester
Providence
Hartford
Trenton
Dover
Baltimore
Rockville
Washington, D.C.
Harrisburg
Columbus
Cincinnati
Charleston
Richmond
Salt Lake City
Cheyenne
Denver
Lincoln
Iowa City
Indianapolis
Springfield
Berkeley
Topeka
Jefferson City
Frankfort
Nashville
Las Vegas
Ponca City
Gastonia
Los Angeles
Santa Fe
Oklahoma City
Little Rock
Columbia
Atlanta
Phoenix
El Paso
Jackson
Montgomery
Pascagoula
Jacksonville
New Orleans
Austin
Miami
Point Barrow
ALASKA
Nome
Fairbanks
Anchorage
Attu
St. Paul Island
Adak
Kodiak
Juneau
Stations Not Shown
Agana, Guam
Honolulu, Hawaii
San Juan, Puerto Rico
Ancon, Canal Zone

FIGURE 1.—RADIATION SURVEILLANCE NETWORK SAMPLING STATIONS

after the end of the sampling period and again 7 days later. The initial 3-day aging of the sample eliminates interference from naturally-occurring radon and thoron daughters. By using the two counts and the Way-Wigner formula (*2*), the age of fission products is estimated, and the activity extrapolated to the time of collection.[1] The daily concentrations and estimated ages of selected samples are reported by the PHS in a monthly RSN report (*1*).

Table 1 lists the twenty highest gross beta concentrations among the samples observed in June. The June 18 sample from Columbus, Ohio, exhibited the highest activity for the month.

The June 1964 average gross beta concentration in air for each station is given in table 2. The network average for June (1.58 pc/m^3) decreased from the May average (1.94 pc/m^3), which appears to have been the "spring peak". The twenty highest samples in June ranged from 4.85 to 6.62 pc/m^3. In May the twenty highest samples ranged from 5.16 to 8.44 pc/m^3. Time profiles of gross beta activity in air for eight RSN stations are shown in figure 2.

TABLE 1.—GROSS BETA ACTIVITY OF THE TWENTY INDIVIDUAL RSN AIR FILTERS HAVING HIGHEST ACTIVITIES DURING JUNE 1964

Station		Date June	Concentration (pc/m^3)
D. C:	Washington	12	5.50
		13	5.16
Del:	Dover	9	4.72
Ill:	Springfield	4	4.84
Ind:	Indianapolis	12	5.12
		17	4.85
Miss:	Jackson	5	5.03
N. Y:	Buffalo	1	4.99
Ohio:	Cincinnati	12	6.10
		18	5.31
	Columbus	12	5.15
		17	5.46
		18	6.62
	Painesville	13	6.32
Pa:	Harrisburg	29	5.90
R. I:	Providence	20	5.50
Vt:	Barre	3	5.54
Va:	Richmond	17	4.84
W. Va:	Charleston	17	5.25
		18	5.86

---

[1] If a sample contains a mixture of fresh and old fission products, the age estimated by the Way-Wigner formula is some intermediate value and cannot be used for estimating date of formation.

TABLE 2.—GROSS BETA ACTIVITY IN SURFACE AIR AND PRECIPITATION, JUNE 1964

Station location		Air surveillance					Precipitation measurements	
		Number of samples	Gross beta activity (pc/m^{3})			Last profile in *RHD*	Average concentration (pc/liter) [b]	Total deposition [b] (nc/m^{2})
			Maximum	Minimum	Average [a]			
Alabama:	Montgomery	22	3.28	0.15	1.27	Aug 64	310	36.3
Alaska:	Adak	27	3.45	<0.10	0.63	Nov 63	[b]	
	Anchorage	29	1.97	<0.10	0.55	Jul 64	360	7.2
	Attu	30	2.41	<0.10	0.63	Dec 63		
	Fairbanks	28	3.15	<0.10	1.27	Aug 64	470	15.5
	Juneau	13	0.72	<0.10	0.33	Sep 64	310	20.4
	Kodiak	20	0.94	<0.10	0.32	Oct 64		
	Nome	7	2.42	<0.10	1.21	Feb 64		
	Point Barrow	0	0	0	0	Jan 64		
	St. Paul Island	27	1.76	<0.10	0.47	Mar 64		
Ariz:	Phoenix	29	3.19	0.46	2.17	Sep 64		
Ark:	Little Rock	29	3.02	0.39	1.37	Sep 64	420	4.6
Calif:	Berkeley	20	0.92	0.15	0.52	Oct 64	250	4.3
	Los Angeles	21	1.82	0.25	0.73	Feb 64	610	4.8
Canal Zone:	Ancon	11	0.11	<0.10	<0.10	Apr 64		
Colo:	Denver	27	3.06	0.42	1.99	Oct 64	520	3.9
Conn:	Hartford	30	3.51	0.76	1.95	Oct 64	470	24.8
Del:	Dover	20	4.72	0.74	2.31	Aug 64		
D. C:	Washington	26	5.50	0.47	2.83	Aug 64	550	15.9
Fla:	Jacksonville	29	2.86	0.28	1.53	Sep 64	270	35.1
	Miami	30	2.42	0.11	0.86	Oct 64	260	58.6
Ga:	Atlanta	30	2.25	0.20	0.89	Jul 64	280	34.9
Guam:	Agana	23	0.60	<0.10	0.21	Apr 64		
Hawaii:	Honolulu	30	3.92	0.30	0.81	Feb 64		
Idaho:	Boise	29	2.58	0.34	1.41	Dec 63	460	23.6
Ill:	Springfield	28	4.84	0.37	1.90	Mar 64	330	10.0
Ind:	Indianapolis	29	5.12	0.55	2.15	Jul 64	610	49.2
Iowa:	Iowa City	29	4.29	0.95	1.96	Jan 64	230	20.9
Kans:	Topeka	22	[illegible].67	0.16	1.03	Jul 64	240	46.4
Ky:	Frankfort	28	4.61	0.57	1.94	Feb 64	340	16.0
La:	New Orleans	29	2.30	0.23	1.02	Mar 64	220	20.8
Maine:	Augusta	29	4.24	0.46	2.28	Mar 64	670	35.6
	Presque Isle	29	3.76	<0.10	1.73	Nov 63		
Md:	Baltimore	22	4.25	0.67	2.20	Oct 64	410	18.3
	Rockville	12	3.55	0.58	1.38	Mar 64		
Mass:	Lawrence	28	3.91	0.82	2.25	Aug 64	980	23.2
	Winchester	27	3.05	0.48	1.60	Apr 64	830	39.5
Mich:	Lansing	28	4.58	0.83	2.68	Feb 64	610	39.0
Minn:	Minneapolis	30	3.11	0.13	1.56	Mar 64	560	31.3
Miss:	Jackson	28	5.03	0.43	1.69	Apr 64	210	17.6
	Pascagoula	0	0	0	0	Dec 63		
Mo:	Jefferson City	30	3.00	0.13	1.26	Jul 64	260	36.7
Mont:	Helena	29	2.99	0.20	1.28	Nov 64	620	38.8
Nebr:	Lincoln	0	0	0	0	Apr 64		
Nev:	Las Vegas	22	3.71	1.53	2.73	Aug 64		
N. H:	Concord	21	4.28	1.10	2.61	Feb 64	480	18.7
N. J:	Trenton	30	4.07	0.64	2.19	Apr 64		
N. Mex:	Santa Fe	22	4.16	0.67	1.65	Dec 63	1,070	5.7
N. Y:	Albany	21	3.30	0.88	1.92	Jul 64	220	3.8
	Buffalo	12	4.99	0.68	2.63	Nov 63	[b]	
	New York	30	3.91	0.71	2.55	Dec 63		
N. C:	Gastonia	30	3.92	0.46	1.70	Jan 64	300	33.9
N. Dak:	Bismarck	28	4.05	0.25	1.93	Feb 64	610	100.0
Ohio:	Cincinnati	19	6.10	0.55	2.10	Aug 64		
	Columbus	30	6.62	0.52	2.50	Apr 64	500	65.6
	Painesville	29	6.32	1.06	3.08	Oct 64	920	39.1
Okla:	Oklahoma	26	3.30	0.20	0.98	Apr 64	200	4.0
	Ponca City	30	1.39	<0.10	0.64	Oct 64	330	21.7
Ore:	Portland	27	3.45	0.20	1.28	Oct 63	330	16.5
Pa:	Harrisburg	29	5.90	0.51	2.04	Jul 64	560	15.4
P. R:	San Juan	29	1.32	0.30	0.72	Mar 64	200	19.5
R. I:	Providence	26	5.50	0.65	2.58	Jan 64	440	9.8
S. C:	Columbia	28	2.43	0.50	1.29	Dec 63	580	37.7
S. Dak:	Pierre	30	2.80	0.26	1.44	Sep 64	340	18.7
Tenn:	Nashville	28	4.71	0.53	1.93	Jan 64	620	23.8
Tex:	Austin	30	2.43	<0.10	0.85	Aug 64	220	18.7
	El Paso	30	2.67	0.71	1.55	Jan 64		
Utah:	Salt Lake City	30	3.49	0.61	1.67	Aug 63	470	34.0
Vt:	Barre	30	5.54	0.92	3.12	Sep 64	790	22.5
Va:	Richmond	30	4.84	0.52	1.92	Sep 64	330	21.9
Wash:	Seattle	30	1.45	<0.10	0.46	Jul 64	400	32.0
W. Va:	Charleston	29	4.71	0.76	2.64	Dec 63	480	27.5
Wisc:	Madison	30	5.86	0.41	1.98	Sep 64	280	15.9
Wyo:	Cheyenne	30	2.69	0.72	1.64	Aug 64	1,390	17.2
Network summary		1,860	6.62	<0.10	1.58		393	25.6

---

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes. If the <0.10 values represent more than 10 percent of the average, a less-than sign is placed before the average.

[b] Blank spaces indicate precipitation not sampled.

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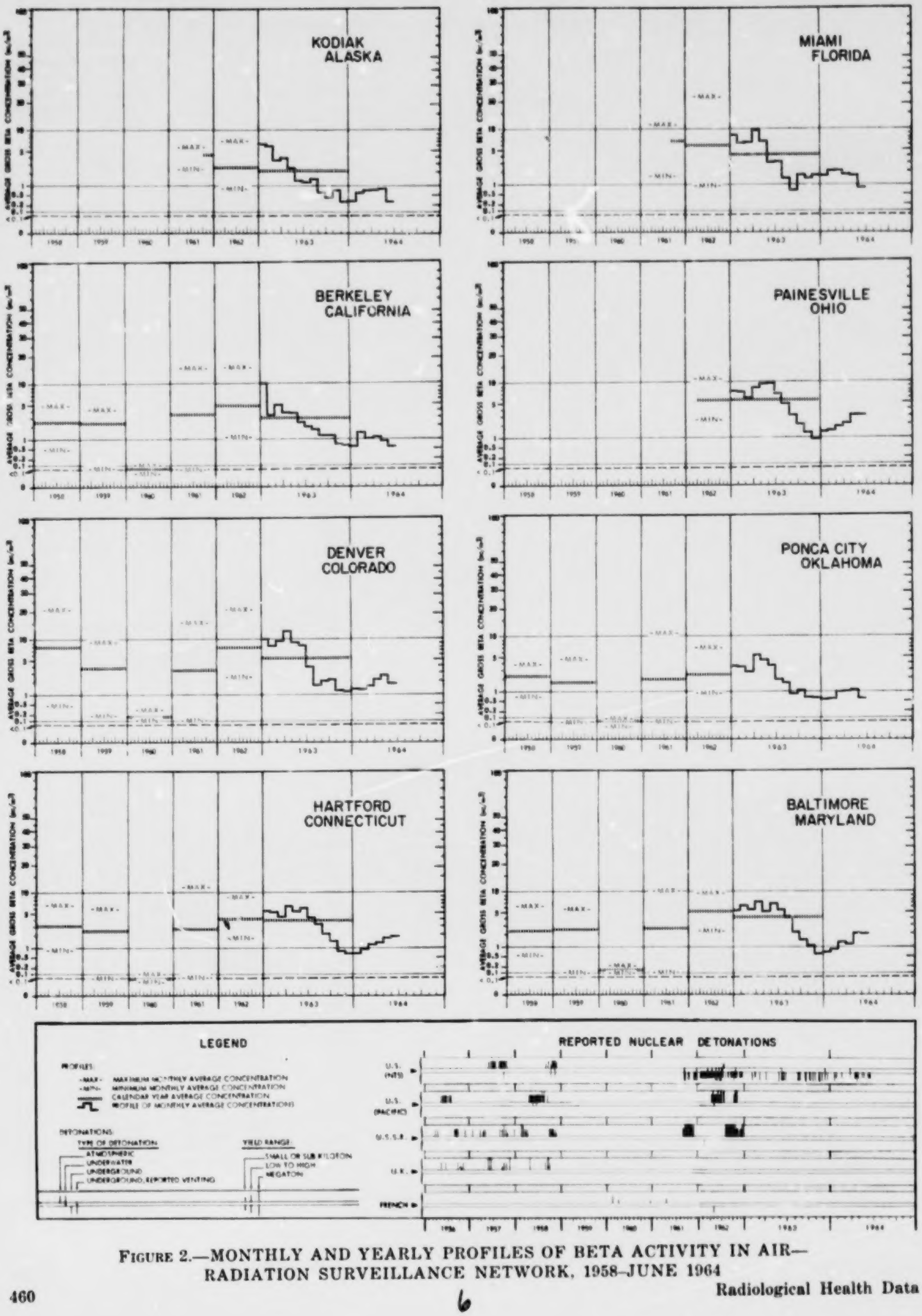


FIGURE 2.—MONTHLY AND YEARLY PROFILES OF BETA ACTIVITY IN AIR—RADIATION SURVEILLANCE NETWORK, 1958–JUNE 1964

Precipitation

Continuous sampling for total precipitation is conducted at most stations on a daily basis, using funnels with collection areas of 0.4 square meter. A 500-ml aliquot of the collected precipitation is evaporated to dryness, and the residue is forwarded to the laboratory for analysis. If the collected sample is between 200 and 500 ml, the entire sample is evaporated. When a sample is smaller than 200 ml (equivalent to 0.5 mm or 0.02 inches of rainfall), the volume of precipitation is reported, but no analysis is made.

In the laboratory the gross beta activity in precipitation is determined by counting the evaporated sample by the same method used for analyzing the air filters, including the extrapolation to time of collection. Deposition for the sample is determined by:

$$D = \frac{CP}{1000}$$

where D is the deposition in nc/m^2, C is the concentration in pc/liter, and P is the depth of precipitation in mm. The individual values of deposition and depth of precipitation are totaled for the month, and the average concentration for the month, $\bar{C}$, is determined by:

$$\bar{C} = \frac{\Sigma D}{\Sigma P} \times 1000$$

The June 1964 average concentrations and total depositions are given in table 2.

2. National Air Sampling Network
Second Quarter 1964

Division of Air Pollution
Public Health Service

The necessity of having basic data on the nature and extent of air pollution throughout the United States led to the organization of the National Air Sampling Network (NASN) in 1953. The NASN analyzes air samples for the total quantity of suspended particulate matter, benzene-soluble organic matter, and gross beta radioactivity. Selected samples are also analyzed for nitrates, sulfates, and a number of metals. These analyses aid in the detection of trends in air quality with respect to time, location, population density, climate and other factors.

Gross Beta Activity in Air

NASN stations (see figure 3) are manned by cooperating Federal, State and local agencies. The current basic network consists of 110 sampling stations which operate every year in 73 large cities and 37 nonurban areas. In addition, there are stations in 130 cities which operate every other year. Thus, there are 240 sampling stations in all in the NASN network, of which 175 are active in any given year.

Continuous 24-hour samples of suspended particulate matter are taken at each station. The samples, representing approximately 2,000 cubic meters of air, are collected on glass fiber filters on a biweekly random sampling schedule. They are then sent for analysis to the Network laboratory at the Robert A. Taft Sanitary Engineering Center in Cincinnati, Ohio. Second quarter 1964 data appear in table 3.

Gross Beta Activity in Precipitation

The present reporting of gross beta activity in precipitation originated in 1959 when a precipitation collection and analysis program was established by the Weather Bureau Research Station in Cincinnati, Ohio, and the National Air Sampling Network. Monthly composite samples of precipitation are collected at 29 stations, which are located at Weather Bureau offices or airports. They are then forwarded to the Network laboratory for analysis.

TABLE 3.—FISSION PRODUCT GROSS BETA ACTIVITY IN SURFACE AIR, NASN, SECOND QUARTER, 1964

[Concentrations in pc/m³]

Station location		Number of samples	Maximum	Minimum	Average
Ala:	Birmingham	6	2.9	0.8	2.0
	Gadsden	7	3.3	0.8	2.0
	Mobile	6	3.2	1.0	2.0
Alaska:	Anchorage	6	3.8	0.3	1.1
Ariz:	Grand Canyon Pk.ᵃ	6	5.0	1.8	3.4
	Maricopa Co.ᵃ	7	8.0	3.3	5.2
	Phoenix	7	5.7	3.0	4.2
	Tucson	7	6.5	1.0	4.0
Ark:	Little Rock	6	3.6	0.3	2.0
	Montgomery Co.ᵃ	7	5.5	0.5	2.8
	Texarkana	6	2.9	0.6	1.7
Calif:	Bakersfield	5	5.6	1.1	2.6
	Burbank	6	3.6	0.9	2.2
	Humboldt Co.ᵃ	6	1.4	0.3	0.6
	Los Angeles	6	1.7	0.3	1.2
	Monterey	5	2.4	0.4	1.3
	Oakland	6	3.6	0.4	1.2
	Pasadena	6	3.8	1.1	2.4
	Sacramento	6	4.9	0.6	2.0
	San Diego	6	4.0	0.7	2.2
	San Francisco	6	2.9	0.5	1.3
	Santa Ana	6	3.2	0.7	1.8
	Santa Barbara	7	2.0	0.7	1.4
Colo:	Denver	7	5.8	1.2	3.1
	Montezuma Co.ᵃ	6	5.7	1.0	2.7
Conn:	Hartford	6	3.5	0.9	2.7
	New Haven	7	4.9	0.6	2.7
Del:	Kent Co.ᵃ	6	4.4	1.3	3.0
	Wilmington	6	4.5	1.2	3.2
D. C:	Washington	7	5.6	0.2	2.9
Fla:	Florida Keys ᵃ	5	4.1	0.9	[illegible]
	Jacksonville	6	4.0	0.9	2.5
	Orlando	6	4.4	1.2	2.4
	Tampa	7	4.5	1.4	2.7
Ga:	Atlanta	6	3.3	0.8	2.0
Hawaii:	Honolulu	7	1.3	0.5	0.9
Idaho:	Boise	6	4.2	0.4	2.1
	Butte Co.ᵃ	6	5.5	0.7	2.5
Ill:	Chicago	5	3.2	0.1	1.7
	Cicero	6	4.0	2.3	2.7
	Moline	6	2.6	0.9	1.8
	Peoria	6	2.7	1.1	1.8
	Rock Island	5	4.6	2.2	3.4
Ind:	East Chicago	5	2.4	1.5	2.0
	Evansville	7	3.9	0.6	2.0
	Fort Wayne	6	4.1	0.8	2.6
	Gary	3	3.7	2.1	2.9
	Indianapolis	7	3.8	0.8	2.8
	Lafayette	6	2.5	0.8	1.9
	Parke Co.ᵃ	7	2.9	1.1	2.1
Iowa:	Davenport	7	3.1	1.4	2.3
	Delaware Co.ᵃ	6	2.3	0.6	1.6
	Des Moines	7	3.6	1.1	2.4
	Dubuque	6	2.3	0.6	1.6
Kans:	Kansas City	5	2.6	1.2	1.9
	Wichita	6	2.0	0.4	2.2
Ky:	Ashland	6	6.5	1.4	3.0
	Covington	6	5.7	1.2	3.0
	Louisville	6	3.0	0.5	2.0
La:	Baton Rouge	6	2.8	1.1	2.0
	Lake Charles	6	3.4	0.6	1.8
	New Orleans	6	3.8	0.8	2.3
Maine:	Acadia Nat'l. Pk.ᵃ	6	2.4	1.7	2.0
	Portland	6	3.5	1.0	2.1
Md:	Baltimore	6	4.6	0.3	3.0
	Calvert Co.ᵃ	6	5.1	0.4	3.4
Mass:	Boston	7	3.5	0.6	2.3
	Springfield	5	3.8	0.4	2.0
Mich:	Detroit	7	4.3	0.6	2.5
	Wyandotte	5	4.7	1.8	3.3
Minn:	Duluth	6	2.7	0.5	1.4
	Minneapolis	6	2.7	0.6	1.5
	Moorhead	6	3.2	1.1	2.2
	St. Paul	6	2.6	0.8	1.5
Miss:	Jackson	6	3.3	0.7	2.1
	Jackson County ᵃ	5	2.5	1.5	1.9
Mo:	Kansas City	5	4.1	0.5	2.4
	Shannon Co.ᵃ	6	3.6	1.8	2.7
	St. Louis	6	3.1	0.7	2.0
Mont:	Glacier Nat'l. Pk.ᵃ	3	2.5	0.9	1.6
	Helena	6	4.6	0.2	2.1
Nebr:	Omaha	6	4.3	0.4	2.7
	Thomas Co.ᵃ	6	6.4	1.2	2.6
Nev:	Las Vegas	6	4.9	2.5	3.3
	White Pine Co.ᵃ	5	4.6	0.8	2.6
N. H:	Concord	6	3.3	0.8	2.1
	Coos Co.ᵃ	7	3.4	0.2	2.0
N. J:	Camden	6	4.6	0.4	3.1
	Jutland	6	4.2	0.2	2.9
	Marlton	3	5.8	2.9	4.1
	Newark	7	3.8	0.3	2.4
	New Brunswick	6	3.5	0.3	2.4
	Pemberton	6	4.4	0.3	2.7
	Perth Amboy	6	5.2	0.3	2.8
	Princeton	5	3.8	0.4	2.6
	Trenton	4	3.3	0.4	2.4
	Glassboro	6	4.5	0.3	3.1
N. M:	Albuquerque	6	5.8	2.6	3.7
	Rio Arriba Co.ᵃ	6	4.8	2.0	3.2
N. Y:	Cape Vincent ᵃ	6	3.2	0.2	2.2
	New York	6	5.7	0.5	3.2
N. C:	Cape Hatteras	6	6.4	0.5	2.3
	Charlotte	7	4.1	1.7	2.7
	Fayetteville	7	4.2	1.7	3.1
	Winston-Salem	6	4.4	0.6	3.0
N. Dak:	Bismarck	6	6.1	1.1	2.8
	Fargo	6	3.3	0.7	1.9
	Ward Co.ᵃ	7	5.3	0.4	2.7
Ohio:	Akron	7	3.7	1.3	2.6
	Cincinnati	6	6.0	1.2	3.3
	Cleveland	6	3.2	0.8	2.0
	Columbus	6	6.5	1.5	2.9
	Dayton	6	6.8	1.6	3.0
	Lorain	6	3.1	0.4	2.0
	Steubenville	6	3.0	1.3	2.0
	Toledo	7	6.5	0.6	3.0
	Youngstown	6	3.6	0.9	2.3
Okla:	Cherokee Co.ᵃ	7	5.0	0.4	2.6
	Oklahoma City	6	4.6	0.5	2.0
	Tulsa	6	3.9	0.4	2.5
Ore:	Portland	6	1.3	0.1	0.6
	Curry County ᵃ	7	3.5	0.7	1.4
Pa:	Clarion Co.ᵃ	5	3.1	1.1	1.9
	Embreeville	6	3.4	0.2	2.2
	Lancaster	7	4.5	0.3	2.7
	Philadelphia	6	4.4	0.3	3.0
	Pittsburgh	6	3.5	0.6	2.0
	West Chester	2	1.7	0.2	1.0
P. R:	Guayanilla	7	2.6	0.9	1.6
	Ponce	7	2.8	1.2	1.8
	San Juan	6	2.7	0.8	1.6
R. I:	Providence	6	4.0	1.2	2.5
	Washington Co.ᵃ	7	5.1	1.7	3.2
S. C:	Columbia	4	4.6	1.6	2.7
	Richland Co.ᵃ	5	3.9	1.5	2.5
S. Dak:	Black Hills	7	4.9	0.5	2.6
	Sioux Falls ᵃ	6	2.5	0.5	1.8
Tenn:	Chattanooga	7	5.1	1.0	2.8
	Memphis	6	5.7	1.2	2.9
	Nashville	6	3.3	1.1	2.3
Tex:	Aransas Co.ᵃ	7	3.1	0.6	1.8
	Dallas	6	3.2	0.5	2.2
	El Paso	6	6.3	1.4	3.6
	Houston	6	4.5	0.5	2.5
	Laredo	6	5.2	0.3	1.6
	San Antonio	6	5.1	0.5	2.6
	Texarkana	6	2.7	0.5	1.8
	Waco	6	3.7	1.2	2.1
Utah:	Ogden	6	3.2	0.9	2.4
	Salt Lake City	6	5.2	0.8	3.1
Vt:	Burlington	7	4.2	0.1	2.0
	Orange Co.ᵃ	6	3.1	0.1	2.2
Va:	Danville	6	6.1	0.5	3.7
	Norfolk	7	5.6	0.7	3.2
	Shenandoah Pk.ᵃ	6	4.2	0.5	2.5
Wash:	Seattle	6	1.6	0.2	0.9
	Tacoma	6	1.7	0.1	0.7
W. Va:	Charleston	7	5.2	1.7	2.8
	Huntington	5	6.8	2.5	3.7
	Parkersburg	6	6.3	1.1	2.9
	Weirton	7	4.2	1.4	2.7
Wis:	Door Co.	7	2.9	0.8	2.0
	Eau Claire ᵃ	7	3.1	0.6	2.3
	Milwaukee	6	3.1	1.5	2.3
	Racine	6	2.4	0.5	1.7
	Superior	6	2.2	0.4	1.0
Wyo:	Cheyenne	6	5.4	1.9	3.1
	Yellowstone Pk.ᵃ	6	3.0	0.4	1.6
Network summary		1,015	8.0	0.1	2.37

ᵃ Nonurban stations.

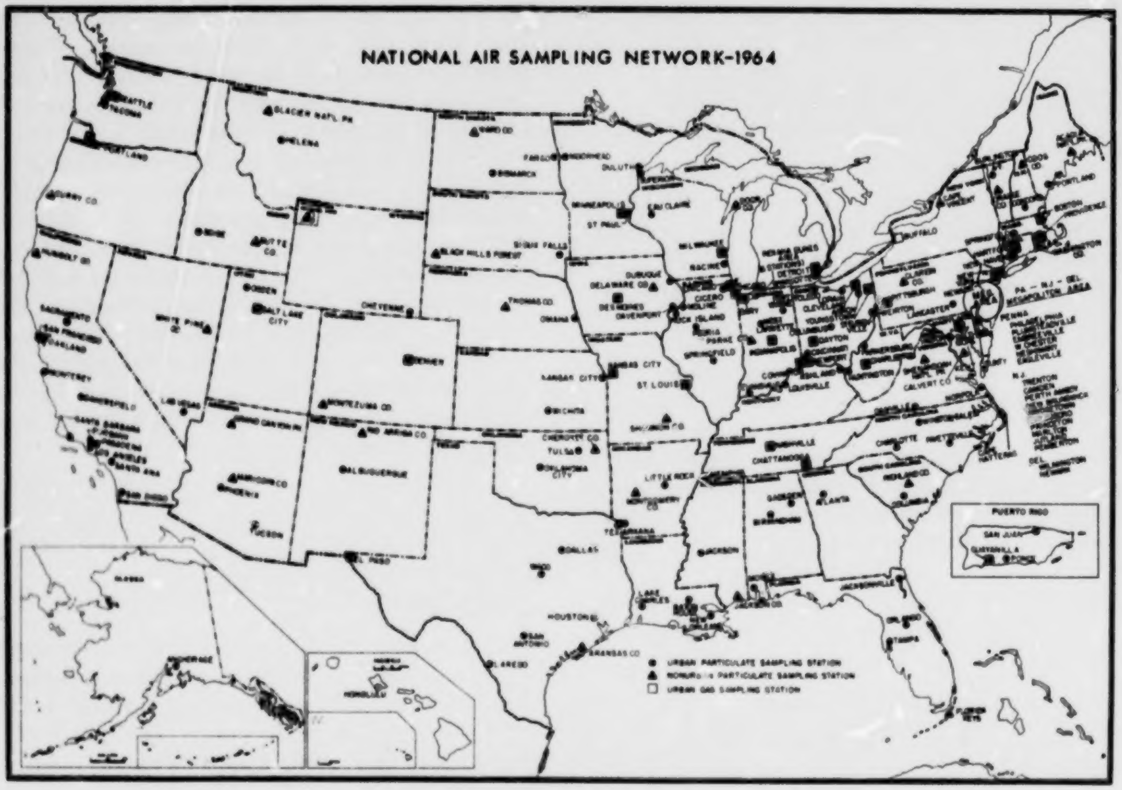

NATIONAL AIR SAMPLING NETWORK-1964
URBAN PARTICULATE SAMPLING STATION
NONURBAN PARTICULATE SAMPLING STATION
URBAN GAS SAMPLING STATION
PUERTO RICO
SAN JUAN

FIGURE 3.—NATIONAL AIR SAMPLING NETWORK SAMPLING STATIONS, 1964

The laboratory analyzes these samples for total solids and for a large number of metals and nonmetals. In addition, each sample is analyzed for fission product gross beta radioactivity if a sufficient volume of precipitation remains after chemical analyses have been made. Precipitation data for April and May 1964 are presented in table 4.

Effective with the June 1964 samples, the responsibility for the conduct of the precipitation program was assumed by the National Center for Atmospheric Research, Boulder, Colorado. No further publication of radioactivity in precipitation data from the NASN is anticipated.

TABLE 4.—GROSS BETA ACTIVITY IN PRECIPITATION, NASN, APRIL AND MAY 1964

Station		April		May	
		pc/liter	nc/m²	pc/liter	nc/m²
Ala:	Montgomery	285	85	555	22
Fla:	Tampa			350	26
Ill:	Chicago (O'Hare)	1245	141		
	Chicago (Midway)	2,250	98		
La:	Lake Charles			465	23
Maine:	Caribou			810	52
Mass:	Nantucket	510	33		
Mich:	Sault Ste. Marie	750	12	970	57
Minn:	St. Cloud	565	45	620	56
Mo:	Columbia	1,075	131	870	81
Mont:	Glasgow			305	12
Nebr:	Grand Island	410	41		
N. Y:	Albany	1,230	62		
N. C:	Cape Hatteras	540	53	570	32
Ohio:	Cincinnati (Airport)	465	75		
	Cincinnati (Gest St.)	575	67		
Pa:	Philadelphia	650	85		
S. C:	Charleston	340	22	480	61
	Greenville	375	111	555	22
Tenn:	Nashville	620	70	450	46
Tex:	Brownsville			245	15
Va:	Sterling	635	53		
Wash:	Tatoosh	475	24		

3. Canadian Air Monitoring Program[2]
June 1964

Department of National Health and Welfare

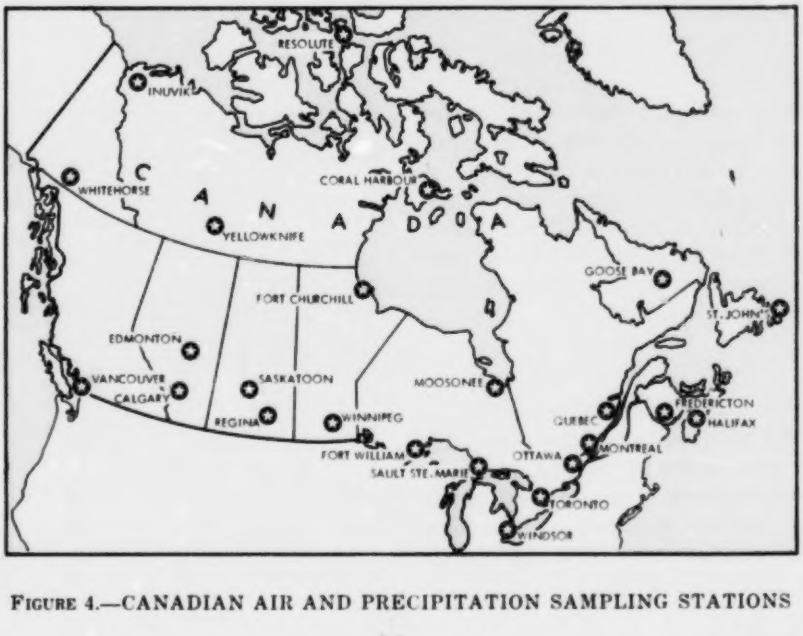
The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (see figure 4), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of the National Health and Welfare (*3–7*).

Air

Each air sample involves the collection of particulates from about 650 cubic meters of air drawn through a high-efficiency 4-inch-diameter filter during a 24-hour period. These filters are sent daily to the Radiation Protection Division Laboratory in Ottawa. At the laboratory, a 2-inch-diameter disk is cut from each filter and counted with a thin-end-window, gas-flow, Geiger-Mueller counter system, calibrated with a Sr^{90}–Y^{90} standard. Four successive measurements are made on each filter to permit correction for natural activities and for the decay of short-lived fission products. The results are extrapolated to the end of the sampling period. Canadian air data for June 1964 are given in table 5 and presented in conjunction with U. S. and Mexican data by an isogram map (figure 6).

Precipitation

The amount of radioactive fallout deposited on the ground is determined from measurements on material collected in special polyethylene-lined rainfall pots. The collection period for each sample is one month. After


RESOLUTE
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WHITEHORSE
YELLOWKNIFE
CORAL HARBOUR
GOOSE BAY
FORT CHURCHILL
ST. JOHN'S
EDMONTON
SASKATOON
VANCOUVER
CALGARY
REGINA
WINNIPEG
MOOSONEE
QUEBEC
FREDERICTON
HALIFAX
FORT WILLIAM
SAULT STE. MARIE
OTTAWA
MONTREAL
TORONTO
WINDSOR

FIGURE 4.—CANADIAN AIR AND PRECIPITATION SAMPLING STATIONS

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[2] Data from *Radiation Protection Programs 7:* 11–24, Radiation Protection Division, Canadian Department of National Health and Welfare, Ottawa, Canada (July 1964).

TABLE 5.—GROSS BETA ACTIVITY IN SURFACE AIR AND PRECIPITATION, CANADA, JUNE 1964

Station	Air surveillance				Precipitation data	
	Number of samples	Gross beta activity (pc/m³)			Average concentration (pc/liter)	Total deposition (nc/m²)
		Maximum	Minimum	Average		
Calgary	29	4.1	0.1	1.6	612	53.6
Coral Harbour	29	1.7	0.1	0.4	962	29.8
Edmonton	29	3.5	0.6	1.9	1,772	46.8
Ft. Churchill	27	1.9	0.1	0.8	868	35.0
Ft. William	30	6.7	0.2	1.6	944	133.4
Fredericton	30	2.5	0.1	1.2	1,077	60.4
Goose Bay	28	5.0	0.1	1.3	598	89.1
Halifax	28	2.8	0.2	1.3	829	49.4
Inuvik	30	3.0	0.2	1.2	872	33.2
Montreal	29	3.8	0.7	2.3	1,214	37.9
Moosonee	30	3.6	0.3	1.5	666	73.6
Ottawa	30	3.2	0.3	2.0	943	29.7
Quebec	30	3.0	0.5	1.9	690	82.0
Regina	28	7.6	0.2	2.4	936	84.1
Resolute	30	1.3	0.1	0.4	1,093	21.9
St. John's, Nfld	28	2.5	0.1	0.9	656	51.8
Saskatoon	28	4.3	0.6	2.5	2,768	46.4
Sault Ste. Marie	30	3.5	0.1	1.6	819	55.1
Toronto	28	4.3	0.5	1.8	541	17.6
Vancouver	30	2.1	0.2	0.6	742	41.6
Whitehorse	30	2.2	0.2	0.9	673	20.8
Windsor	26	3.6	0.5	2.1	868	84.8
Winnipeg	28	3.3	0.2	1.7	681	81.0
Yellowknife	29	2.9	0.3	1.5	3,253	16.5
Network summary		3.4	0.3	1.5	1,045	53.1

transfer of the water to the sample container, the polyethylene liner is removed, packed with the sample, and sent to the laboratory.

Strontium and cesium carriers are added to all samples on arrival at the laboratory. Other carriers are also added to selected samples according to the specific radionuclides to be determined. The samples are then filtered and the filtrate evaporated to near dryness. The filter paper containing insoluble matter is ignited together with the polyethylene liner at 450°C. The ash is combined with the soluble fraction, transferred to a glass planchet, evaporated under an infra-red lamp and then counted with a thin-end-window Geiger-Mueller counter calibrated with a Sr^{90}–Y^{90} source. Gross beta activities for June 1964 samples are given in table 5. Radionuclide analyses are reported quarterly in *RHD*.

4. Mexican Air Monitoring Program June 1964

National Commission of Nuclear Energy

The Radiation Surveillance Network of Mexico was established by the *Comisión Nacional de Energía Nuclear* (CNEN), Mexico City. From 1952 to 1961 the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN (*8–12*).

In 1961 the CNEN appointed its Division of Radiological Protection (DRP) to establish a new Radiation Surveillance network. This network consists of 17 stations (see figure 5), twelve of which are located at airports and operated by airline personnel. The remaining five stations are located at Mexico City, Mérida, Veracruz, San Luis Potosí and Ensenada. Staff members of the DRP operate the station at Mexico City while the other four stations are manned by members of the Centro de Previsión del Golfo de México, the Chemistry Department of the University of Mérida, the Institute de Zonas Dersérticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air for 24 hours a day, 3 or 4 days a week at the rate of approximately 1,200 cubic meters per day, through a high-efficiency, 6 x 8-inch glass fiber filter, using high volume samplers. After each 24 hour sampling period, the filter is removed and forwarded via air mail to the "Laboratorio de Estudios sobre Contaminación Radiactiva", CNEN, in Mexico City for assay of gross beta activity. A minimum of 3 or 4 days after collections is allowed for decay of radon and thoron daughter natural radioactivity. Data are not extrapolated to time of collection.

Results

The maximum, minimum and average fission product beta concentrations in surface air during June 1964, are presented in table 6. The data are also represented in the beta activity isogram map of North America, figure 6.

TABLE 6.—GROSS BETA ACTIVITY OF AIRBORNE PARTICULATES, MEXICO, JUNE 1964

[Concentrations in pc/m³]

Station	Number of Samples	Maximum	Minimum	Average
Acapulco	9	1.0	0.1	0.4
Ciudad Juárez	25	1.8	0.4	1.1
Chihuahua	20	1.9	0.4	1.3
Ensenada	8	1.6	0.2	0.9
Guadalajara	11	2.0	0.3	1.1
Guaymas	9	3.2	0.6	1.3
La Paz	22	2.2	0.1	1.1
Matamoros	8	1.3	0.2	0.8
Mazatlán	14	2.9	0.9	1.7
Mérida	17	2.0	0.2	0.9
México, D.F.	22	1.4	[illegible]	0.7
Nuevo Laredo	14	1.3	0.2	0.9
San Luis Potosí	18	2.1	0.2	1.2
Tampico	18	1.6	0.1	0.8
Torreón	18	3.5	0.6	1.9
Tuxtla Gutiérrez [a]				
Veracruz	20	2.3	0.1	1.1

[a] Temporarily shut down.

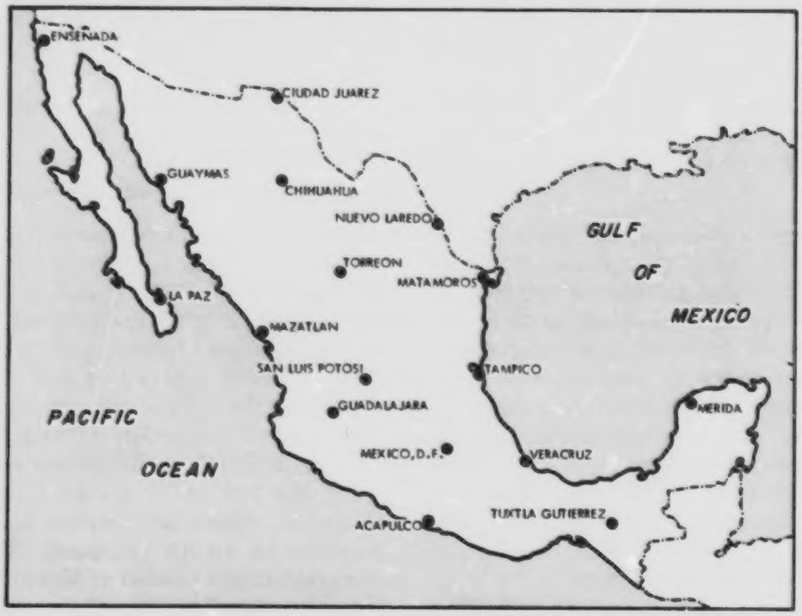
ENSENADA
CIUDAD JUAREZ
GUAYMAS
CHIHUAHUA
NUEVO LAREDO
TORREON
MATAMOROS
GULF
OF
MEXICO
LA PAZ
MAZATLAN
SAN LUIS POTOSI
TAMPICO
MERIDA
GUADALAJARA
PACIFIC
OCEAN
MEXICO, D.F.
VERACRUZ
TUXTLA GUTIERREZ
ACAPULCO

FIGURE 5.—FALLOUT NETWORK SAMPLING STATIONS IN MEXICO

5. Pan American Air Sampling Program June 1964

Pan American Health Organization and Public Health Service

Gross beta activity in air is monitored by four countries in the Americas under the auspices of a collaborative program developed by the Pan American Health Organization and the Public Health Service (PHS) for assisting countries of the Americas in developing radiological health programs. The sampling equipment and analytical services are provided by the Division of Radiological Health, PHS, and are identical with those employed for the Radiation Surveillance Network.

The four air sampling stations included in the program are operated by the technical staff of the Ministry of Health in each country. The station in Kingston, Jamaica, is operated by the Public General Hospital; in Caracas, Venezuela, by the Venezuelan Institute for Scientific Investigations; in Lima, Peru, by the Institute of Occupational Health; and in Santiago, Chile, by the Occupational Health Service. The Kingston station began operation in March 1964 and the other three were started near the end of 1962.

The June 1964 air monitoring results from the four participating countries are given in table 7. The Caracas and Jamaica stations, included in figure 6 with the June averages adjusted by the RSN intercalibration factor,[3] were used in positioning the beta concentration isograms.

TABLE 7.—GROSS BETA ACTIVITY IN AIR, JUNE 1964

[Concentrations in pc/m³]

Sampling stations	No. of samples	Maximum	Minimum	Average [a]
Kingston, Jamaica	17	0.92	0.22	0.43
Caracas, Venezuela	21	0.38	<0.10	0.19
Lima, Peru	19	0.31	<0.10	0.11
Santiago, Chile	19	0.19	<0.10	0.17

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes. If the <0.10 values represent more than 10 percent of the average, a less-than sign is placed in front of the average.

6. Gross Beta Activity in Air, North America June 1964

Beginning with January 1963 data, monthly average concentrations of airborne gross beta activity in Canada and the United States have been presented in combined form as isogram maps of most of North America. The data from the Radiation Surveillance Network and the Canadian Air Network were adjusted to each other by means of an intercalibration factor derived by Lockhart and Patterson (*13*).

With the formation of the Mexican Air monitoring program, new intercalibration ratios were determined, this time including the Canadian Network, Radiation Surveillance Network, National Air Sampling Network, the HASL 80th Meridian Network, and the Mexican Network (*14*). The new intercalibration factors reflect some changes in standardization in both the RSN and the Canadian Air Network, effective September 1963.

Figure 6 shows the June 1964 activity in air throughout North America based on the data from the Canadian Air Monitoring Program, the Radiation Surveillance Network and Mexican Air Monitoring program. An intercalibration factor of 1.28 was applied to the RSN data and the Mexican data were multiplied by 0.81 in order to adjust them to Canadian data.

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[3] The RSN factor is 1.28.

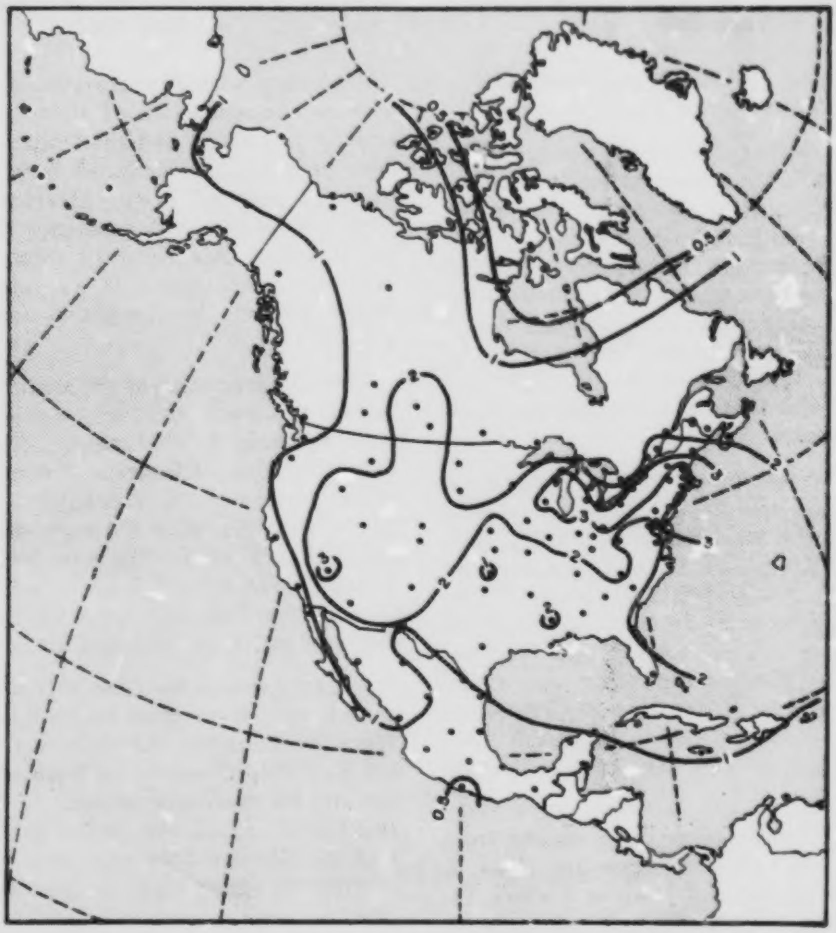

FIGURE 6.—ISOGRAMS OF AVERAGE GROSS BETA CONCENTRATIONS IN AIR, NORTH AMERICA, JUNE 1964

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FISSION PRODUCT GAMMA ACTIVITY IN SURFACE AIR—80TH MERIDIAN AND U.S. LOCATIONS, MAY 1964

William R. Collins, Jr.[1]

Fourteen air sampling stations near the 80th Meridian (West) from Thule, Greenland, to Punta Arenas, Chile, make up the Health and Safety Laboratory (HASL) 80th Meridian Network (figure 1). An additional station at Mauna Loa, Hawaii, is included for comparing data with that from Chacaltaya, Bolivia; both are at a high elevation and their respective latitudes North and South are nearly equal. Data are also reported for the six additional stations in the United States, as described in the August 1964 *RHD* (*1*).

Air particulates are sampled on 8-inch-diameter polystyrene filters drawing air through the filters continuously at the rate of about 1400 cubic meters per day. Filters are changed at noon on the 1st, 8th, 15th, and 22nd of each month and forwarded to HASL for analysis. A total gamma count is made approximately

TABLE 1.—GAMMA ACTIVITY IN SURFACE AIR, 80TH MERIDIAN NETWORK AND U.S. STATIONS, MAY 1964

[Activity in gamma photons/min/m^3]

Station latitude, elevation	May sampling periods				May average
	1-7	8-15	16-21	22-31	
80TH MERIDIAN NETWORK:					
Thule, Greenland 77° N, 259 m	0.923	1.02	1.42	0.656	0.972
Moosonee, Canada 51° N, 10 m	1.64	0.647	0.938	0.706	0.950
New York, N. Y. 41° N, 38 m	2.14	1.83	1.65	1.42	1.76
Washington, D. C. 39° N, 82 m	1.51	1.76	1.49	1.62	1.60
Miami, Fla. 26° N, 4 m	0.724	1.58	1.00	0.889	1.05
Mauna Loa, Hawaii 19° N, 3394 m	1.32	1.99	0.770	0.638	1.11
San Juan, P. R. 18° N, 10 m	0.836	0.950	0.939	0.604	0.823
Miraflores, Canal Zone 9° N, 10 m	0.269	0.717	0.738	0.108	0.419
Guayaquil, Ecuador 0°-08′ S, 7 m	0.0235	0.0278	0.0370	0.0275	0.0289
Lima, Peru 12° S, 30 m	0.0464	0.0407	0.0287	0.0408	0.0401
Chacaltaya, Bolivia 17° S, 5220 m	0.0602	0.0586	0.0493	0.0702	0.0603
Antofagasta, Chile 24° S, 519 m	0.0459	0.0526	0.0435	0.0407	0.0452
Santiago, Chile 33° S, 5 m	0.0541	0.0443	0.0530	0.0344	0.0458
Puerto Montt, Chile 41° S, 5 m	0.0191	0.0430	0.0554	0.0405	0.0396
Punta Arenas, Chile 53° S, 3 m	0.0505	0.0504	0.0408	0.0411	0.0454
ADDED U.S. STATIONS:					
Westwood, N. J. 41°00′ N, 38 m	1.56	1.29	1.29	1.37	1.38
Chattanooga, Tenn. 35°33′ N, 206 m	1.71	1.49	1.98	1.48	1.66
Appleton, Wisc. 44°15′ N, 229 m	1.54	1.18	1.36	1.26	1.34
Midwest City, Okla. 35°25′ N, 364 m	1.91	1.95	1.84	1.46	1.79
Palo Alto, Calif. 47°36′ N, 3 m	0.660	1.11	1.07	1.03	0.968
Seattle, Wash. 37°30′ N, 19 m	0.913	1.00	1.14	1.24	1.07

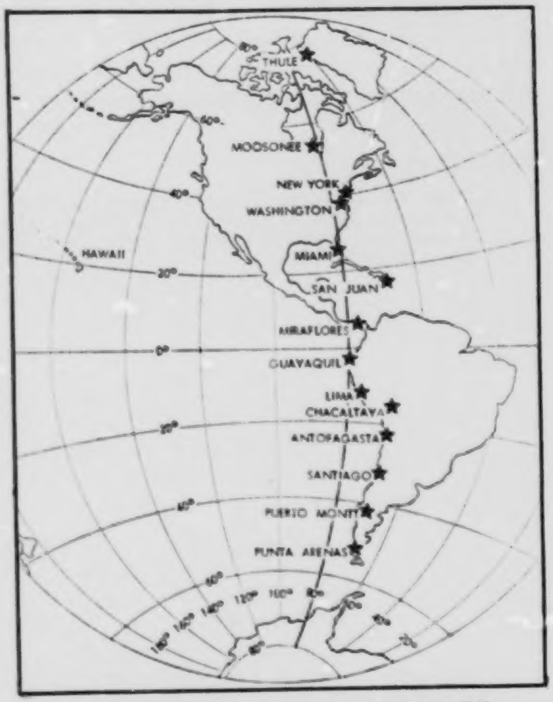

FIGURE 1.—80TH MERIDIAN NETWORK SAMPLING STATIONS (6 NEW U. S. STATIONS NOT SHOWN)

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[1] Mr. Collins is a chemist on the staff of the Environmental Studies Division, Health and Safety Laboratory, U. S. Atomic Energy Commission.

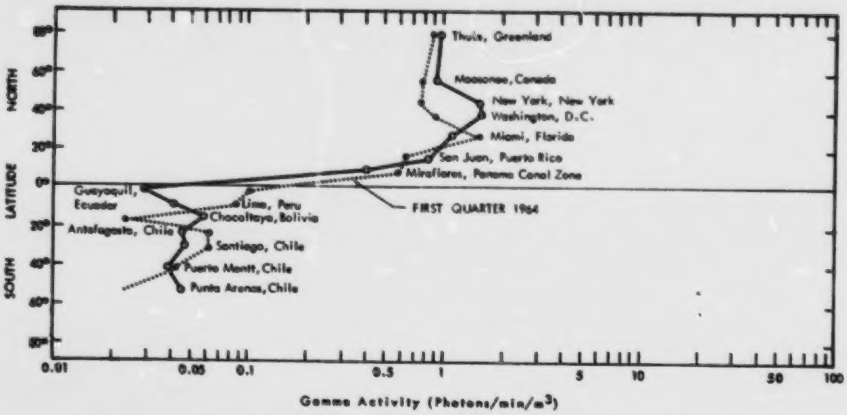

FIGURE 2.—PROFILES OF SURFACE AIR GAMMA ACTIVITY, FIRST QUARTER AND MAY 1964

two weeks after the midpoint of the sampling period, using an 8 x 4-inch sodium iodide (thallium-activated) crystal.

The results of total gamma activity determinations in weekly ground level air filter samples taken at all sampling locations during May 1964 are listed in table 1 together with average monthly activity concentrations calculated for each site. The average monthly activities are also plotted in figure 2 as activity—latitude profiles.

The data show that surface activities at the 80th Meridian sites in the Northern Hemisphere[2] ranged from 0.11 to 2.1 γ/min/m^3 (photons per minute per cubic meter), with an average of 1.1 γ/mm/m^3. In the Southern Hemisphere the range was from 0.019 to 0.070 γ/min/m^3, with an average of 0.044 γ/min/m^3. In comparison to previous data, the May 1964 averages represent an increase with respect to the previous month of about 10 percent in the Northern Hemisphere and a decrease of about 10 percent in the Southern Hemisphere. With respect to the May 1963 values, decreases of 85 percent and 50 percent occurred in the Northern and Southern Hemispheres, respectively.

REFERENCE

(*1*) Collins, W. R.: Fission Product Gamma Activity in Surface Air—80th Meridian and U. S. Locations, March and April 1964, *Radiological Health Data, 5:* 360–62. (August 1964).

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[2] Does not include six additional U.S. stations.

Section II—Milk and Food

MILK SURVEILLANCE

Although milk is only one of the many sources of dietary intake of radionuclides, it is the single food item most often used as an indicator of the population's intake of radionuclides from the environment. This is because fresh milk is consumed by a large segment of the United States population and contains most of the radionuclides occurring in the environment which have been identified as biologically important. In addition, milk is produced and consumed on a regular basis, is convenient to handle, is easily analyzed, and samples which are representative of milk consumption in any area can be readily obtained.

1. Pasteurized Milk Network, June 1964

Division of Radiological Health and Division of Environmental Engineering and Food Protection, Public Health Service

The Public Health Service pasteurized milk radionuclide surveillance program had its origin in a raw milk monitoring network (*1*) established by the Service in 1957. One of the primary objectives of this network was the development of methods for milk collection and radiochemical analysis suitable for larger scale programs.

Experience derived from this earlier network led to the activation of a pasteurized milk sampling program with stations selected to provide nationwide surveillance of milk production and consumption areas. The present network, which consists of 63 stations, has at least one station in every State, the Canal Zone, and Puerto Rico.

Sampling Procedure

Through the cooperation of State and local milk sanitation authorities, samples are routinely collected at each station. Composites of the samples are preserved with formaldehyde and are sent to the PHS Southwestern (SWRHL), Southeastern (SERHL), or Northeastern Radiological Health Laboratories (NERHL) for analysis. Gamma analyses for iodine–131 are made within 3 to 6 days after sample collection, and any results exceeding 100 pc/liter are immediately telephoned to State health officials for possible public health action. Analytical results are normally available 6 to 7 weeks after monthly samples are received by the laboratories; publication in *RHD* follows 3 to 4 months after the monthly samples are composited for analyses.

The method specifies that each station's sample be composited of subsamples from each milk processing plant in proportion to the plant's average sales in the community served. At most stations the composited sample represents from 80 to 100 percent of the milk processed. Prior to September 15, 1961, the composite sample was taken from one day's sales per month and was as representative of the community's supply as could be achieved under practical conditions. Beginning with the resumption of nuclear weapons testing in the atmosphere in September 1961, and continuing through January 1963, samples were collected twice a week at nearly all stations and daily for short periods at selected stations. Since then, the sampling frequency has been reduced to once a week.

Analytical Procedures

Iodine–131, cesium–137, and barium–140 concentrations are determined by gamma scintillation spectroscopy.[1] After the weekly samples are gamma scanned, samples from two consecutive weeks are composited and analyzed radiochemically for strontium–89 and strontium–90. There is an inherent statistical variation associated with all measurements of radionuclide concentrations. With the low radionuclide levels which are usually found in milk and other environmental samples, this variation on a percentage basis is relatively high. The variation depends upon such factors as the method of chemical analysis, the sample counting rate and counting time, interferences from other radionuclides and the background count. For milk samples, counting times of 50 minutes for gamma spectroscopy and 30 to 50 minutes for beta determinations are used. Table 1 shows the approximate total analytical error (including counting error) associated with radionuclide concentrations in milk. These errors were determined by comparing results of a large number of replicate analyses. Table 1 gives the 95 percent confidence limits between which the true concentrations of the selected radionuclides might be expected in the individual analyses. The minimum detectable concentration is defined as the measured concentration at which the two-standard-deviation analytical error is equal to the measurement. Accordingly, the minimum detectable concentrations in units of pc/liter are Sr^{89}, 5; Sr^{90}, 2; Cs^{137}, 10; Ba^{140}, 10; and I^{131}, 10. At these levels and below, the counting error comprises nearly all of the analytical error.

Calcium analyses at SERHL are done by an ion exchange and permanganate titration method while at NERHL and SWRHL an ethylenediaminetetraacetic acid (EDTA) method is used. Stable potassium concentrations are estimated from the potassium–40 concentrations[2] determined from the gamma spectrum.

TABLE 1.—ANALYTICAL ERRORS ASSOCIATED WITH ESTIMATED CONCENTRATIONS FOR SELECTED RADIONUCLIDES IN MILK

Nuclide	Estimated concentration (pc/liter)	Error [a] (pc/liter)	Estimated concentration (pc/liter)	Error [a] (percent of concentration)
Iodine-131	0 to 100	±10	100 or greater	±10%
Barium-140	0 to 100	±10	100 or greater	±10%
Cesium-137	0 to 100	±10	100 or greater	±10%
Strontium-89	0 to 50	±5	50 or greater	±10%
Strontium-90	0 to 20	±2	20 or greater	±10%

[a] Two standard deviations (2σ).

Data Presentation

Table 2 presents summaries of the analyses for June 1964 (May 31–June 23, 1964). Although not shown in table 2, the iodine–131 and barium–140 monthly average concentrations in milk were less than 10 pc/liter. Radionuclide values reported by a laboratory as being below the minimum detectable concentration have been averaged by using one-half the minimum detectable value. The averaging procedure was modified for iodine–131 and barium–140 in October 1963, when nondetectable concentrations of these radionuclides were considered zero. A similar procedure is used for the network average.

Figures 1 and 2 are isogram maps showing the estimated strontium–90 and cesium–137 concentrations in milk over the entire country. The value printed beside each station is the monthly average concentration for that station. The isograms were developed by arbitrary interpolation between values for the individual stations. Additional modification to the isograms are made according to available information on milksheds.

In table 3, the distribution of the network's stations with respect to radionuclide concentrations in milk, has been developed from the averages shown in table 2.

The average monthly strontium–90 concentrations in pasteurized milk from selected cities in the sampling program are presented in figure 3. Each graph shows the strontium–90 concentrations in milk from one city in each of the four U. S. Bureau of Census regions. The method of selection permits graphic presentation of data for each city in the network three times a year. The last column in table 2 shows the most recent issue in which a graph of the strontium–90 concentration was given for each station. A tabulation of the network monthly maximum, minimum, and average radionuclide concentration in milk was given for March 1960–March 1964 in the July 1964 issue of *RHD* (*2*).

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[1] Southeastern Radiological Health Laboratory employs a radiochemical procedure for barium–140 analysis.

[2] The conversion factor is 1.18 x 10^{-3} g K/pc K^{40}.

TABLE 2.—STABLE ELEMENT AND RADIONUCLIDE CONCENTRATIONS IN PASTEURIZED MILK, JUNE 1964 [a]

[Average radioactivity concentrations in pc/liter]

Sampling locations		Calcium (g/liter)		Potassium (g/liter)		Strontium-89		Strontium-90		Cesium-137		Last Sr^{90} graph in *RHD* (1964)
		Second quarter	Avg. for month	Second quarter	Avg. for month	Second quarter	Avg. for month	Second quarter	Avg. for month	Second quarter	Avg. for month	
Ala:	Montgomery	1.15	1.16	1.5	1.6	<5	<5	26	23	90	80	Oct
Alaska:	Palmer	1.22	1.18	1.4	1.4	5	5	25	28	150	140	July
Ariz:	Phoenix	1.17	1.17	1.5	1.5	<5	<5	6	5	30	20	Sept
Ark:	Little Rock	1.15	1.15	1.5	1.5	<5	<5	58	49	160	120	July
Calif:	Sacramento	1.24	1.25	1.5	1.5	<5	5	9	8	50	55	Aug
	San Francisco	1.22	1.23	1.4	1.4	<5	<5	12	8	55	50	Oct
Canal Zone:	Cristobal	1.09	1.10	1.5	1.5	<5	<5	6	6	55	50	July
Colo:	Denver	1.22	1.20	1.5	1.5	<5	<5	22	26	90	100	Aug
Conn:	Hartford	1.14	1.14	1.5	1.5	<5	<5	23	23	160	155	Aug
Del:	Wilmington	1.20	1.19	1.5	1.4	<5	<5	30	28	145	130	Sept
D. C:	Washington	1.12	1.14	1.6	1.6	<5	<5	23	24	100	85	Oct
Fla:	Tampa	1.13	1.13	1.5	1.4	<5	<5	15	14	260	270	Sept
Ga:	Atlanta	1.15	1.14	1.5	1.5	<5	<5	36	30	165	130	Oct
Hawaii:	Honolulu	1.16	1.20	1.6	1.5	<5	<5	11	11	85	90	July
Idaho:	Idaho Falls	1.21	1.24	1.4	1.5	10	<5	34	33	205	195	Sept
Ill:	Chicago	1.16	1.13	1.5	1.5	<5	<5	19	23	130	115	Oct
Ind:	Indianapolis	1.20	1.18	1.5	1.5	<5	<5	25	25	110	110	Aug
Iowa:	Des Moines	1.22	1.20	1.4	1.4	5	5	30	28	100	90	Sept
Kans:	Wichita	1.19	1.18	1.4	1.4	5	5	25	30	80	75	July
Ky:	Louisville	1.13	1.13	1.5	1.6	<5	<5	37	36	100	85	Sept
La:	New Orleans	1.18	1.17	1.5	1.5	<5	<5	59	53	180	140	July
Maine:	Portland	1.18	1.17	1.5	1.5	<5	<5	33	35	210	200	Sept
Md:	Baltimore	1.13	1.14	1.5	1.4	<5	<5	28	31	125	105	Sept
Mass:	Boston	1.18	1.16	1.6	1.5	<5	<5	38	43	245	240	Oct
Mich:	Detroit	1.17	1.16	1.5	1.5	<5	<5	21	23	120	105	Aug
	Grand Rapids	1.22	1.19	1.5	1.4	<5	<5	23	26	135	120	Sept
Minn:	Minneapolis	1.22	1.19	1.5	1.5	10	<5	37	42	160	155	Oct
Miss:	Jackson	1.22	1.20	1.5	1.5	<5	<5	53	44	125	100	Aug
Mo:	Kansas City	1.19	1.20	1.4	1.4	10	5	32	30	100	90	Aug
	St. Louis	1.21	1.22	1.4	1.4	10	10	28	28	95	100	July
Mont:	Helena	1.19	1.20	1.5	1.5	5	<5	32	32	195	155	July
Nebr:	Omaha	1.21	1.22	1.5	1.5	5	5	30	31	105	85	Sept
Nev:	Las Vegas	1.20	1.24	1.5	1.5	<5	<5	10	10	90	95	Oct
N. H:	Manchester	1.19	1.18	1.5	1.5	<5	<5	33	36	250	235	Sept
N. J:	Trenton	1.16	1.13	1.5	1.5	<5	<5	23	25	135	125	Aug
N. Mex:	Albuquerque	1.19	1.16	1.5	1.5	5	<5	14	14	70	60	July
N. Y:	Buffalo	1.15	1.12	1.5	1.5	<5	<5	24	28	160	150	Aug
	New York	1.14	1.13	1.5	1.5	<5	<5	30	36	180	170	Oct
	Syracuse	1.16	1.17	1.6	1.5	<5	<5	23	23	160	145	July
N. C:	Charlotte	1.16	1.16	1.5	1.5	<5	<5	43	47	140	135	July
N. Dak:	Minot	1.20	1.20	1.5	1.5	15	10	72	76	175	180	Sept
Ohio:	Cincinnati	1.18	1.16	1.5	1.4	<5	<5	28	26	105	100	Aug
	Cleveland	1.18	1.19	1.5	1.5	<5	<5	25	31	135	140	July
Okla:	Oklahoma City	1.13	1.12	1.6	1.5	<5	<5	27	26	75	75	Oct
Ore:	Portland	1.26	1.27	1.4	1.4	10	10	40	42	190	220	Aug
Pa:	Philadelphia	1.17	1.16	1.5	1.4	<5	<5	25	26	140	120	July
	Pittsburgh	1.18	1.18	1.5	1.5	<5	<5	34	40	175	175	July
P. R:	San Juan	1.11	1.13	1.5	1.5	<5	<5	15	14	90	75	July
R. I:	Providence	1.17	1.16	1.5	1.5	<5	<5	27	30	180	180	Sept
S. C:	Charleston	1.16	1.16	1.5	1.4	<5	<5	35	34	145	120	Aug
S. Dak:	Rapid City	1.14	1.18	1.5	1.5	10	10	48	58	155	170	Oct
Tenn:	Chattanooga	1.17	1.18	1.4	1.4	<5	<5	51	46	145	125	Oct
	Memphis	1.16	1.17	1.5	1.6	<5	<5	42	40	85	70	Sept
Tex:	Austin	1.11	1.12	1.6	1.6	<5	<5	10	10	45	50	Oct
	Dallas	1.12	1.12	1.5	1.5	<5	<5	22	21	70	65	Aug
Utah:	Salt Lake City	1.24	1.21	1.5	1.5	10	5	30	29	195	170	July
Vt:	Burlington	1.18	1.16	1.5	1.5	<5	<5	30	34	190	170	Aug
Va:	Norfolk	1.13	1.16	1.5	1.5	<5	<5	28	28	110	105	Aug
Wash:	Seattle	1.21	1.20	1.5	1.5	10	10	36	40	190	265	Oct
	Spokane	1.27	1.27	1.5	1.5	10	10	29	30	155	150	Aug
W. Va:	Charleston	1.13	1.16	1.5	1.6	<5	<5	34	34	95	80	Oct
Wis:	Milwaukee	1.23	1.22	1.6	1.6	<5	<5	21	21	145	135	Sept
Wyo:	Laramie	1.22	1.18	1.4	1.4	15	20	25	29	120	130	Sept
Network average		1.18	1.17	1.5	1.5	<5	<5	28.9	29.5	133	126	Nov. 63

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[a] The monthly average iodine-131 and barium-140 concentration at each station was <10 pc/liter.

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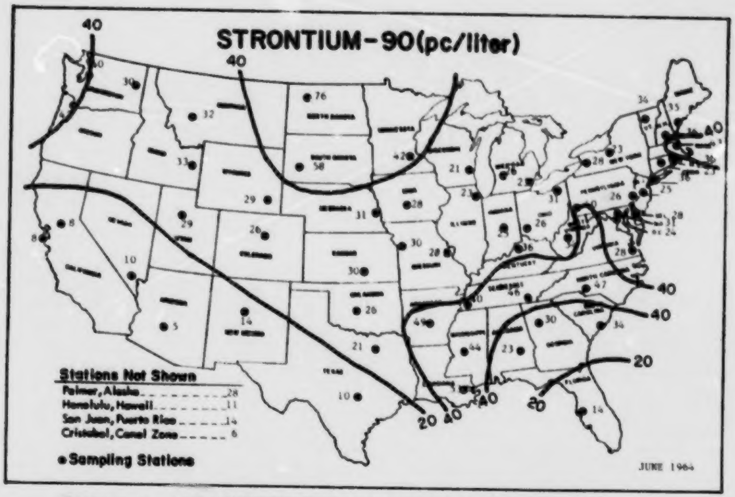
STRONTIUM-90(pc/liter)
Stations Not Shown
Palmer, Alaska 28
Honolulu, Hawaii 11
San Juan, Puerto Rico 14
Cristobal, Canal Zone 6
• Sampling Stations
JUNE 1964
40
20

FIGURE 1.—STRONTIUM-90 CONCENTRATIONS IN PASTEURIZED MILK, JUNE 1964

TABLE 3.—DISTRIBUTION OF SAMPLING STATIONS IN VARIOUS RANGES OF RADIONUCLIDE CONCENTRATIONS IN MILK, JUNE 1964

Strontium-89		Strontium-90		Iodine-131		Cesium-137		Barium-140	
(pc/liter)	Number of stations	(pc/liter)	Number of stations	(pc/liter)	Number of stations	(pc/liter)	Number of stations	(pc/liter)	Number of stations
<5	49	<1-9	4	<10	63	<5-45	1	<10	63
5	7	10-19	6			50-95	19		
10	6	20-29	23			100-145	24		
20	1	30-39	17			150-195	13		
		40-49	10			200-245	4		
		50-59	2			250-295	2		
		60-69							
		70-79	1						

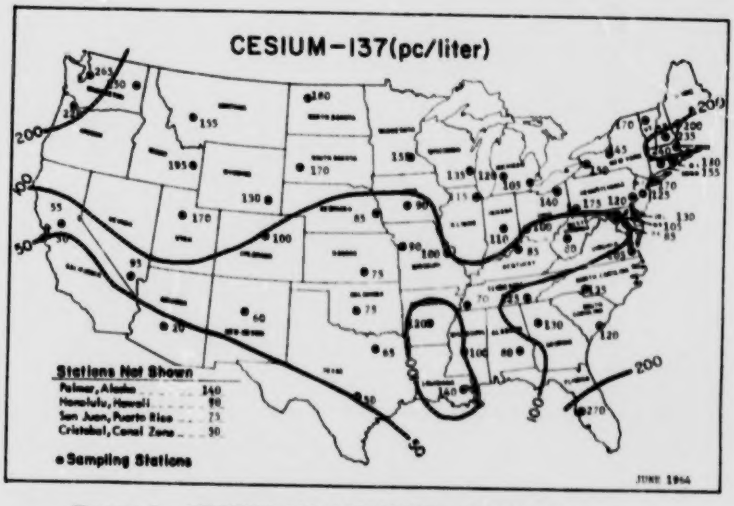
CESIUM-137(pc/liter)
Stations Not Shown
Palmer, Alaska 140
Honolulu, Hawaii 90
San Juan, Puerto Rico 75
Cristobal, Canal Zone 30
• Sampling Stations
JUNE 1964
200
100
50

FIGURE 2.—CESIUM-137 CONCENTRATIONS IN PASTEURIZED MILK, JUNE 1964

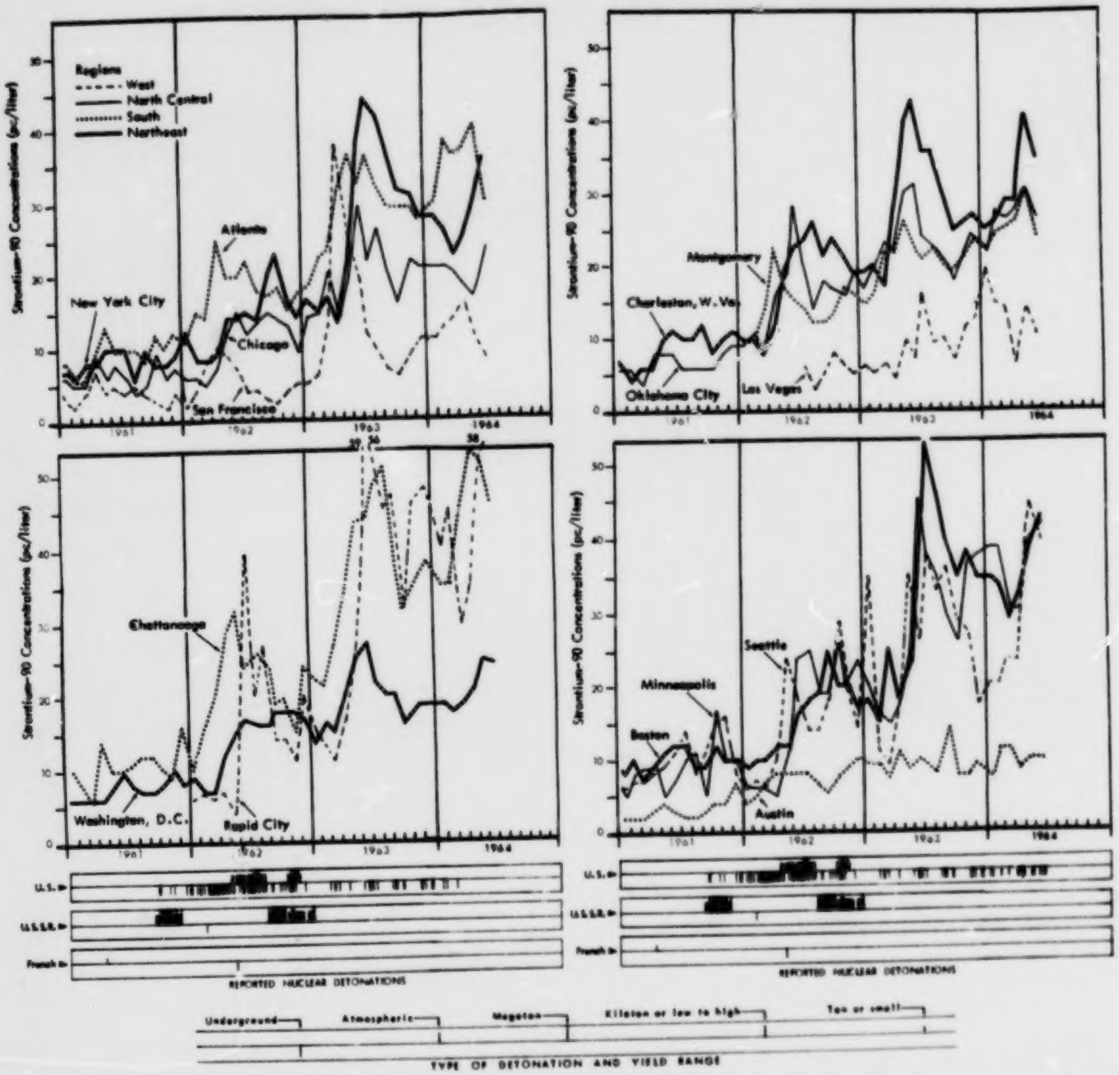

FIGURE 3.—STRONTIUM-90 IN PASTEURIZED MILK, 1961–JUNE 1964

2. Colorado Milk Network
January 1962-June 1964

Occupational and Radiological Health Division
Colorado State Department of Public Health

The Radiological Health Division of the Colorado State Department of Public Health initiated radiological analysis of milk in January 1962. The Denver Health Department collects weekly pasteurized milk composited samples from all major producers in the Denver area.

The State is divided into three major milk producing areas: west, northeast, and southeast. Routine sampling of raw milk began in August 1962. Raw milk shipped into Colorado from eastern Utah was also sampled. The four source areas are shown in figure 4. Sampling in the west and southeast was discontinued in

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Table 4.—RADIONUCLIDES IN COLORADO MILK, JANUARY 1962-JUNE 1964 [a]

[Concentrations in pc/liter]

DATE		RAW MILK												PASTEURIZED MILK		
		Northeast			Southeast			West			Eastern Utah			Denver		
		K^{40}	I^{131}	Cs^{137}	K^{40}	I^{131}	Cs^{137}	K^{40}	I^{131}	Cs^{137}	K^{40}	I^{131}	Cs^{137}	K^{40}	I^{131}	Cs^{137}
1962	Jan	1.50	<20	28	[b]			1.61	<20	<20						
	Feb													1.83	<20	40
	Mar													1.63	<20	27
	Apr													1.64	<20	21
	May													1.60	<20	28
	Jun													1.31	<20	72
	Jul															
	Aug							1.58	93	72	1.56	290	117	1.58	77	70
	Sep	1.70	95	84	1.64	<20	22	1.78	52	70	1.66	30	71	1.62	35	65
	Oct	1.50	77	41	1.55	<20	45	1.50	64	67	1.60	34	143	1.62	27	70
	Nov	1.53	66	48	1.45	41	60	1.50	26	48	1.40	<20	48	1.60	<20	54
	Dec	1.60	<20	89	1.58	<20	49	1.48	22	44	1.60	<20	80	1.52	<20	55
1963	Jan				1.50	<20	60	1.50	<20	36	1.40	<20	100	1.53	<20	64
	Feb	1.46	<20	62	1.56	<20	58	1.50	<20	30	1.50	<20	73	1.50	<20	64
	Mar	1.61	<20	90	1.52	<20	62	1.40	<20	<20	1.60	<20	150	1.52	<20	68
	Apr	1.44	<20	45	1.44	<20	55	1.42	<20	34	1.60	<20	167	1.41	<20	57
	May	1.52	<20	69	1.52	<20	53	1.51	<20	46	1.50	<20	122	1.47	<20	70
	Jun	1.41	<20	129	1.39	<20	120	1.38	<20	67	1.30	<20	122	1.51	<20	112
	Jul	1.40	<20	135	1.57	<20	90	1.50	<20	141	1.50	<20	326	1.50	<20	134
	Aug	1.41	<20	130	1.55		100	1.40	<20	109				1.58	<20	116
	Sep															
	Oct	1.53	<20	79							1.58	<20	239	1.40	<20	98
	Nov	1.58	<20	107										1.50	<20	135
	Dec															
1964	Jan	1.29	<20	95							1.37	<20	133	1.53	<20	9[illegible]
	Feb	1.16	<20	100							1.09	<20	211	1.21	<20	97
	Mar	1.47	<20	104							1.53	<20	236	1.22	<20	100
	Apr	1.32	<20	84										1.64	<20	108
	May	1.28	<20	70							1.34	<20	186	1.33	<20	94
	Jun	1.39	<20	96							1.57	<20	2[illegible]6	1.40	<20	125

[a] Barium-140 monthly averages were <20 pc/liter.

[b] Blanks indicate no analysis.

September 1962. The frequency of sampling varies from one to seventeen times per month in each active sampling area.

Samples are analyzed with the Division's low level counting facilities. The shield is an eight-foot cube having five-inch steel walls lined with one-eighth inch of lead on the inside. A two-quart milk sample in a stainless steel container is analyzed with a 3- x 5-inch thallium-activated

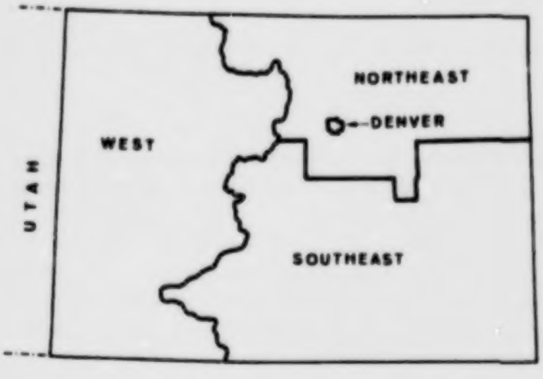

Figure 4.—COLORADO MILK SAMPLING AREAS

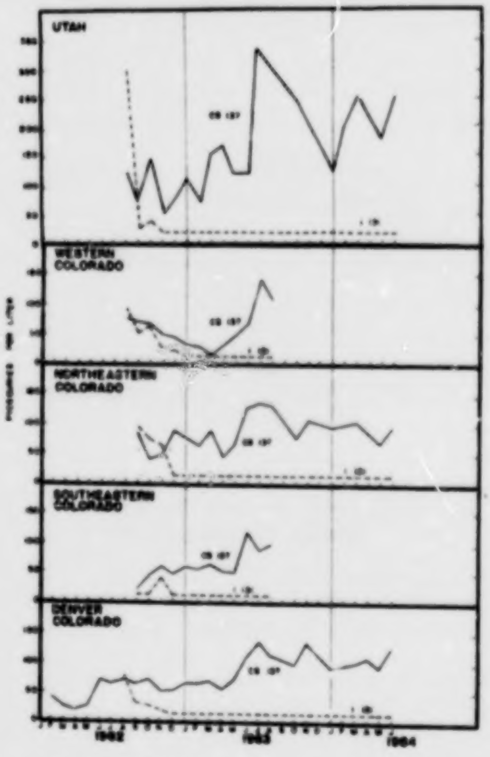

Figure 5.—RADIONUCLIDES IN COLORADO MILK

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sodium iodide crystal and a 512-channel pulse height analyzer for forty minutes. The system is calibrated for routine calculation by the matrix method for the radionuclides iodine-131, barium-140, cesium-137, and potassium-40. The minimum detectable amount for the first three radionuclides at the 95 percent confidence level (± two standard deviations) is 20 pc/liter.

Table 4 gives the radionuclide concentration in milk samples collected from January 1962 through June 1964. These data are presented graphically in figure 5.

3. Florida Milk Network, 1963

Division of Radiological and
Occupational Health
Florida State Board of Health

The Florida State Board of Health began sampling raw milk for iodine-131 analysis in two major areas of the State in November 1962. The program has since been expanded to include the analysis of milk for strontium-89, strontium-90 and cesium-137 in addition to iodine-131. Raw milk samples are received from the six areas shown in figure 6. Samples for iodine-131 analysis are taken from a tank truck, the route of which passes by farms widely dispersed over the area represented. Where there is no route representative of a large portion of the area, samples are collected from selected farms and combined. Presently, the sampling is on a monthly basis. Samples were collected weekly when iodine-131 was detectable in milk. A regional State Board of Health Laboratory is located in each area of the State where samples representing raw milk production are collected. For strontium-89, strontium-90 and cesium-137 analysis, monthly composite samples are prepared by each regional laboratory from a randomly selected 10 percent of the farms which have their milk regularly sampled for bacteriological analyses by the county health departments. These composite samples are then sent to the State Radiological Health Laboratory in Orlando for analysis. Milk produced in the counties comprising each area is generally processed, marketed, and consumed in that area. These areas are characterized by differences in dairying practices related to the gradual transition from small farms—using locally grown feeds in the "West Florida" region—to larger farms using different types of grass and predominantly purchased feeds in the southern areas.

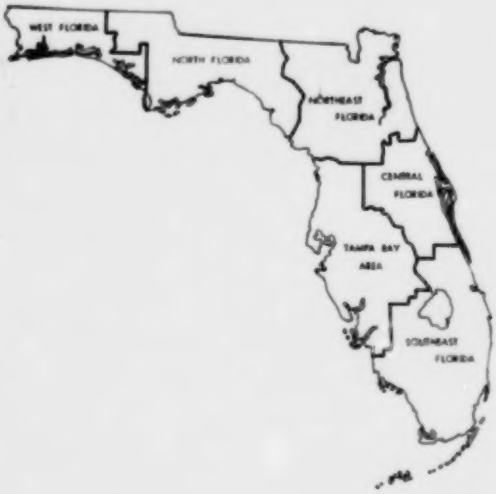

FIGURE 6.—FLORIDA MILK SAMPLING LOCATIONS

Analytical Procedures

Cesium-137 is determined by gamma scanning one liter or 3.5 liters of milk as received in a Marinelli beaker on a 4" x 4" NaI crystal and multichannel analyzer. The sample is then prepared for radiostrontium analysis by evaporating and ashing one liter.

Strontium is precipitated as a carbonate and stored for yttrium ingrowth. After the ingrowth period, yttrium is separated with carrier as an oxalate and counted in a low-background beta counter to determine strontium-90. Strontium is precipitated as carbonate and counted for total radiostrontium activity. Strontium-89 is then calculated by difference.

Results and Discussion

Tables 5, 6, and 7 present all available monthly average strontium-90, strontium-89 and cesium-137 concentrations in Florida milk during 1963. Iodine-131 results for 1963 appeared in the March 1964 issue of *RHD* (3).

TABLE 5.—STRONTIUM-89 IN FLORIDA RAW MILK, 1963

[Concentrations in pc/liter]

Month (1963)	West Florida	North Florida	Northeast Florida	Central Florida	Tampa Bay	Southeast Florida	Average
January	57	49	30	23	22	43	38
February	29	46	43	49	40	30	39
March	43	46	52	70	66	69	58
April	64	55	30	77	33	64	54
May	61	59	58	44	47	64	56
June	53	61	54	26	22	26	40
July	25	21	18	19	23	18	21
August	22	18	17	16	19	17	18
September	19	13	18	16	14	20	17
October	8	6	8	8	10	6	8
November	3	6	8	7	4	6	6
December	4	5	<5	<5	8	<5	5
Average	32	32	28	30	26	31	30

TABLE 6.—STRONTIUM-90 IN FLORIDA RAW MILK, 1963

[Concentrations in pc/liter]

Month (1963)	West Florida	North Flordia	Northeast Florida	Central Florida	Tampa Bay	Southeast Florida	Average
January	4.6	6.5	5.4	[illegible]	3.8	6.1	5.1
February	6.3	4.7	15.0	[illegible]	6.2	3.1	6.6
March	4.1	3.8	7.1	[illegible]	13.8	16.1	10.4
April	9.6	6.1	4.3	7.2	6.8	9.5	7.2
May	15.0	14.7	17.7	16.1	13.1	15.4	15.3
June	11.2	17.5	6.8	16.0	5.2	11.9	11.4
July	6.0	4.0	6.0	4.0	9.0	4.0	5.5
August	7.0	6.0	11.0	9.0	12.0	7.0	8.7
September	10.0	9.0	10.0	12.0	8.0	7.0	9.3
October	20.0	22.0	11.0	12.0	9.0	7.0	13.5
November	15.0	12.0	7.0	11.0	9.0	11.0	10.8
December	16.0	9.0	8.0	8.0	8.0	12.0	10.2
Average	10.4	9.6	9.1	10.1	8.7	9.2	9.5

TABLE 7.—CESIUM-137 IN FLORIDA RAW MILK, APRIL-DECEMBER 1963

[Concentrations in pc/liter]

Month (1963)	West Florida	North Florida	Northeast Florida	Central Florida	Southeast Florida	Tampa Bay	Average
April	141	207	231	245	215	238	213
May	181	231	136	195	183	201	188
June	163	105	149	178	127	220	157
July	204	132	286	237	177	180	206
August	202	176	261	283	221	238	230
September	197	248	313	296	254	236	257
October	175	161	268	223	238	218	214
November	186	180	190	162	219	[illegible]	193
December	172	186	214	225	185	212	199
Average	180	183	228	227	202	218	206

Comparison of the Public Health Service Pasteurized Milk Network data for Tampa, Florida, for 1963 (May 1963–April 1964 issues of *RHD*) with the results from the Florida State Board of Health's Tampa Bay Area gives an indication of the agreement of the two sampling methods: raw milk composites from a sampling of farms and pasteurized milk composites from processing plants. These two sampling techniques provide estimates of the yearly average strontium–90 concentrations in raw and pasteurized milk that are within 38 percent of each other. Yearly average strontium–89 concentrations in raw and pasteurized milk have been within 14 percent of each other. For cesium–137 concentrations, the two methods gave average results within 15 percent of each other for April–December 1963 when analyses were being done.

4. Indiana Milk Network, June 1964

Bureau of Environmental Sanitation
Indiana State Board of Health

The Indiana State Board of Health began sampling pasteurized milk for radiological analysis in September 1961. Indiana was geographically divided into five major milksheds, and one large dairy within each milkshed was selected as a sampling station (figure 7).

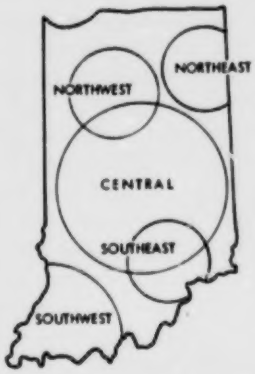

FIGURE 7.—INDIANA MILK SAMPLING LOCATIONS

The milk samples are routinely analyzed for iodine-131, cesium-137, barium-140, strontium-89 and strontium-90. Until August 1963, analyses for the gamma emitters iodine-131, cesium-137 and barium-140 were conducted on a weekly basis, except when iodine-131 exceeded 100 pc/liter, at which times the frequency of sampling was increased. Because of continued low concentrations of the short-lived gamma emitters, the sampling frequency was reduced in August 1963 to once per month for the northeast, southeast and southwest milksheds. Strontium-89 and strontium-90 analyses are performed monthly for each station.

An ion exchange analytical procedure (4) is employed for strontium-89 and strontium-90 analyses. Minimum detectable levels for strontium-89 and strontium-90 are about 5 and 1 pc/liter, respectively. A 512-channel pulse height analyzer and shielded 4 x 4-inch sodium iodide crystal are used for the gamma analysis of iodine-131, cesium-137 and barium-140. Analyses of counting statistics indicate that the lower limit of detectability for both iodine-131 and barium-140 is 5 pc/liter. Cesium-137 analyses are subject to a 6 percent error at the 100 pc/liter level. Additional factors such as drift of the analyzer and calibration factors will increase these limits to some extent.

The monthly averages of the data obtained for the individual sampling stations and the State averages are reported in table 8.

TABLE 8.—RADIONUCLIDES IN INDIANA MILK, JUNE 1964 [a]

[Radionuclide concentrations in pc/liter]

Sampling location	Calcium (g/liter)	K^{40}	Sr^{90}	Cs^{137}
Northeast	1.17	1,280	21	110
Southeast	1.17	1,170	19	105
Central	1.17	1,230	19	80
Southwest	[b]	[b]	[b]	[b]
Northwest	1.17	1,240	22	120
State average	1.17	1,230	21	105

[a] The monthly average iodine-131, barium-140, and strontium-89 concentrations at each station was zero.

[b] No sample collected.

5. New York Milk Network, April 1964

Division of Environmental Health Services
State of New York Department of Health

Milk samples collected routinely from six cities—Albany, Buffalo, Massena, Newburgh, New York, and Syracuse (figure 8) are analyzed for their radionuclide content by the State of New York Department of Health. Pasteurized milk samples are collected daily and composited weekly for the determination of strontium-89, strontium-90, iodine-131, cesium-137 and barium-lanthanum-140 at all stations except Massena, where samples are composited bi-weekly, and at New York where one daily milk sample representing the total milk supply for that day is obtained and analyzed once per week. Samples are obtained from processing plants except at Albany, where the daily sample is obtained from a marketing point. During periods when cows are no longer on stored feed, the sample from Albany is analyzed daily for iodine-131. In the event that any city reports iodine-131 concentrations exceeding 100 pc/liter, increased surveillance is undertaken.

A matrix method (5) is used for the analysis of spectral data to determine the concentrations of gamma-emitting nuclides in milk. With this method, the individual nuclide contributions to the gamma spectrum are separated by solution of simultaneous equations describing the spectral interferences.

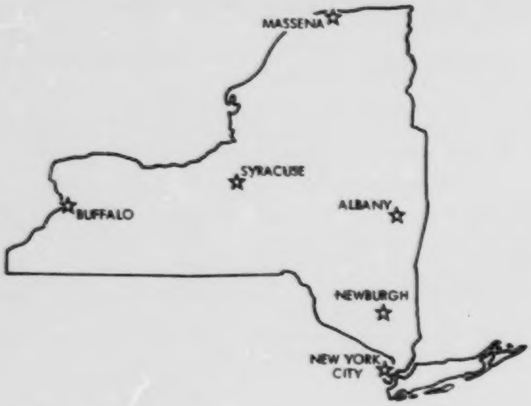

FIGURE 8.—NEW YORK MILK SAMPLING LOCATIONS

The analytical procedure for strontium-89 and strontium-90 is based on ion exchange methods. Cations (including radiostrontium) are eluted from the ion exchange resin with sodium chloride solution, strontium isotopes are gathered by means of sodium carbonate, isolated by means of ethylenediaminetetraacetic acid (EDTA), and radiostrontium is counted with a low background beta counter having an 0.8 mg/cm^2 window. The strontium-90 portion is differentially estimated by a second count 40 hours later to determine the rate of ingrowth of its daughter product yttrium-90. The monthly average radionuclide concentrations in milk are shown in table 9.

TABLE 9.—RADIONUCLIDES IN NEW YORK MILK, APRIL 1964 [a]

[Average concentrations in pc/liter]

Sampling location	Strontium-89	Strontium-90	Cesium-137
Albany	<3	19	126
Buffalo	4	13	112
Massena	8	29	187
Newburgh	4	18	137
New York City	4	23	129
Syracuse	3	19	108
Average	4	20	133

[a] The monthly average I^{131} and $Ba\text{-}La^{140}$ (in equilibrium) at each station was <20 pc/liter.

6. Pennsylvania Milk Network April-June 1964

Bureau of Environmental Health
Pennsylvania Department of Health

Samples of pasteurized milk are routinely collected from 10 major milk consumption areas throughout Pennsylvania (figure 9). Two samples per week are collected in Philadelphia and Pittsburgh, while weekly composite samples are collected from the other eight stations. At each sampling location subsamples are collected from the major dairies supplying the area and are composited in proportion to the amount of milk processed by each dairy. This composite is then sent to the Radiation Laboratory of the Division of Occupational Health in Harrisburg where the weekly samples are combined for monthly analyses. Iodine-131 analyses were begun in September 1961, and strontium-90 analyses were started in April 1963. The gamma analyses of these samples for potassium-40, iodine-131, cesium-137, and barium-140-lanthanum-140 was begun in March 1964.

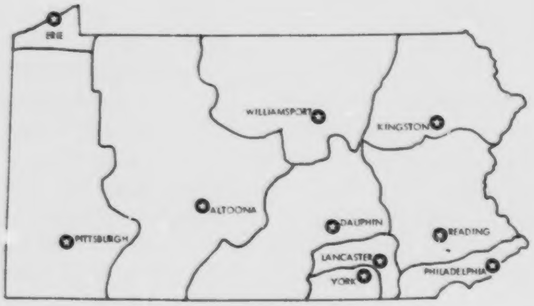

FIGURE 9.—PENNSYLVANIA MILK SAMPLING STATIONS AND MILK CONSUMPTION AREAS

The chemical separation technique for strontium-90 is essentially an ion exchange method described by Porter, *et al.* (4). One liter of milk is passed through an ion exchange column; yttrium-90 is eluted from the resin and is counted in an automatic low background proportional counter.

The monthly average radionuclide levels in pasteurized milk are shown in table 10.

TABLE 10.—STRONTIUM-90 IN PENNSYLVANIA MILK, APRIL-JULY 1964

[Concentrations in pc/liter]

Sampling location	April	May	June	July
Altoona	20	42	37	43
Dauphin	19	39	27	26
Erie	21	37	33	34
Kingston	21	30	36	36
Lancaster	18	29	24	22
Philadelphia	21	35	31	38
Pittsburgh	21	41	38	39
Reading	16	29	25	24
Williamsport	17	32	27	39
York	15	25	20	25
State average	18.9	33.9	29.8	32.6

7. Canadian Milk Network[3]
June 1964

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Department of National Health and Welfare began monitoring milk for strontium–90 in November 1955. At first, analyses were carried out on samples of powdered milk obtained from processing plants. However, since January 1963, liquid whole milk has been analyzed instead. With this change, more representative samples of milk consumed can be obtained, and in addition it is possible to choose milk sampling locations (see figure 10) in the same areas as the air and precipitation stations. At present, the analyses include determinations of iodine–131, strontium–89, cesium–137, and strontium–90 as well as stable potassium and calcium.

The milk samples are obtained through the cooperation of the Marketing Division of the Canadian Department of Agriculture. At each station samples are collected three times a week from selected dairies and are combined into weekly composites and forwarded to the radiochemical laboratory in Ottawa. The contribution of each dairy to the composite sample is directly proportional to its volume of sales. In most cases a complete sample represents over 80 percent of the milk processed and distributed in the area. Several of the weekly samples are randomly selected and analyzed for iodine–131. The results of the spot checks for iodine–131 will not be reported unless there is evidence that the levels are rising. A monthly composite of the samples is analyzed for strontium–90, cesium–137, and stable potassium and calcium.

Analytical Procedures

Radiochemical methods are used for the analysis of iodine–131 (*6*). For the analysis of radiostrontium, carrier strontium is added to a one-liter sample of milk, and the milk is then placed in a tray lined with a polyethylene sheet and evaporated under infra-red lamps. The residue is ashed in a muffle furnace at 450° C, dissolved in dilute nitric acid, and strontium separated by fuming nitric acid precipitation. The combined strontium–89 and strontium–90 are determined by counting in a low background beta counter. Strontium–90 is determined separately by extracting and counting the yttrium–90 daughter nuclide while strontium–89 is estimated by difference from the total radiostrontium measurement. Appropriate corrections are made for self-absorption and counter efficiency at all stages. Calcium is determined by flame photometry.

Cesium–137 is determined by gamma spectroscopy using a scintillation crystal and a multi-channel pulse height analyzer. A sample consisting of 4.5 liters of milk is placed in a sample tray constructed in the form of an inverted well to accommodate the 5- x 4-inch sodium iodide crystal detector. The sample is counted for 100 minutes and the gamma spectrum recorded. Estimates are made of the potassium–40 and cesium–137 content of the milk by comparison of the spectrum with the spectra of standard preparations of these two radionuclides. With this method, the potassium–40 concentration is determined and the Compton contribution of this radionuclide to the cesium–137 photopeak is subtracted to obtain the cesium–137 concentration. The stable potassium content is estimated from the potassium–40 concentration.

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[3] Data from *Radiation Protection Programs, Vol. 2, No. 7:* 25–29, Radiation Protection Division, Canadian Department of National Health and Welfare, Ottawa, Canada (July 1964).

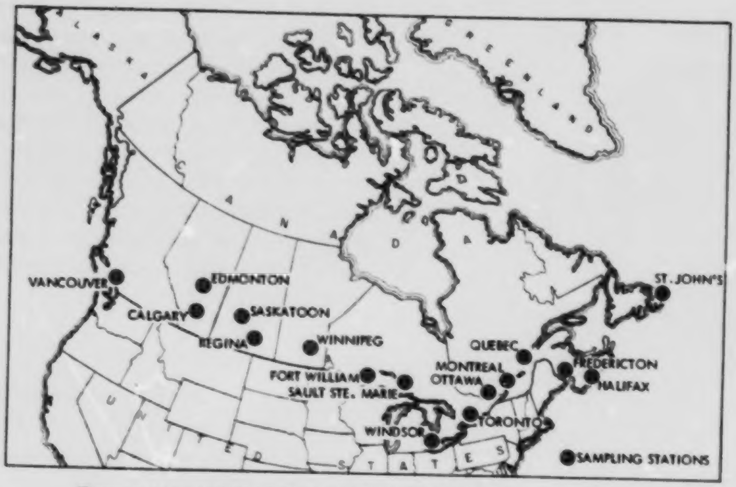
ALASKA
GREENLAND
CANADA
VANCOUVER
EDMONTON
CALGARY
SASKATOON
REGINA
WINNIPEG
FORT WILLIAM
SAULT STE. MARIE
WINDSOR
TORONTO
OTTAWA
MONTREAL
QUEBEC
FREDERICTON
HALIFAX
ST. JOHN'S
UNITED STATES
● SAMPLING STATIONS

FIGURE 10.—CANADIAN MILK SAMPLING STATIONS

Sources of Error

In the iodine and strontium determinations, tests indicate that the statistical error (95 percent confidence level) in the chemical operations involved is about plus-or-minus 10 percent. This value is independent of the concentration of the radioisotope in the milk because it depends only on the recovery of the carrier. In the determination of cesium–137 this factor is not involved.

The chemical procedures error must be combined with the counting error which depends primarily on the concentration of the nuclide in the sample, the background radiation, and the length of time the sample and background are counted. This counting error has been evaluated mathematically for the particular counting arrangement used.

The overall errors, estimated on the basis indicated above, are given in table 11.

TABLE 11.—TOTAL ERROR FOR VARIOUS RADIONUCLIDE CONCENTRATIONS IN MILK [a]

Nuclide	Error for 10 pc/liter	Error for 50 pc/liter	Error for 100 pc/liter
Strontium-89	±25%	±20%	±15%
Strontium-90	±15%	±10%	±10%
Iodine-131	±50%	±20%	±10%
Cesium-137	±60%	±25%	±10%

[a] All errors are 2σ values, representing 95 percent confidence levels.

Results

Table 12 presents monthly averages of strontium–90, cesium–137 and stable calcium and potassium in Canadian whole milk. Spot checks for iodine–131 and strontium–89 indicate that all samples had <5 pc/liter. Figure 11 shows

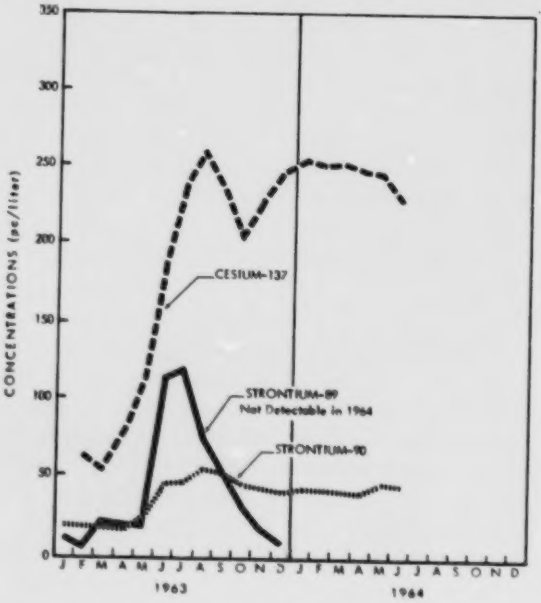

FIGURE 11.—NETWORK AVERAGE STRONTIUM-89, STRONTIUM-90, AND CESIUM-137 CONCENTRATIONS IN CANADIAN WHOLE MILK

the variation of the network average of the radionuclide concentration in Canadian whole milk.

TABLE 12.—RADIONUCLIDES IN CANADIAN WHOLE MILK, JUNE 1964

Station	Calcium (g/liter)	Potassium (g/liter)	Strontium-90	Cesium-137
Calgary	1.46	1.5	44.4	184
Edmonton	1.39	1.6	40.0	177
Ft. William	1.40	1.6	66.8	314
Fredericton	1.43	1.6	47.9	271
Halifax	1.47	1.6	54.7	317
Montreal	1.42	1.7	37.3	198
Ottawa	1.41	1.6	29.0	155
Quebec	1.42	1.6	32.1	282
Regina	1.35	1.6	36.0	156
St. John's, Nfld	1.35	1.7	38.3	339
Saskatoon	1.36	1.6	30.5	116
Sault Ste. Marie	1.38	1.6	32.8	257
Toronto	1.42	1.6	17.9	114
Vancouver	1.49	1.6	55.5	488
Windsor	1.44	1.6	20.4	109
Winnipeg	1.22	1.6	35.7	159
Average	1.40	1.6	42.5	227

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MOVING ANNUAL AVERAGE RADIONUCLIDE CONCENTRATIONS IN PASTEURIZED MILK, JULY 1963–JUNE 1964

Division of Radiological Health, Public Health Service

Radionuclide concentration values reported by the Pasteurized Milk Network (*1*) can be used to estimate the contribution of milk to a population's radiation exposure. This is done by determining both the annual average concentrations of specific radionuclides in milk and the average daily milk consumption of a representative individual in a suitable sample of the population.

The data listed in table 1 are concerned with the first of these requirements, *i.e.*, annual average concentrations of strontium–89, strontium–90, and cesium–137 in one liter of pasteurized milk. Limited data are available for estimating the average daily milk consumption (on a volume basis) for specific age groups in the U.S. population (*2, 3*).

To arrive at a basis of comparison between the daily rates of intake of the radionuclides from the milk component of the diet and the Federal Radiation Council's ranges of transient daily rates of intake (*4*), it is assumed that the average daily milk consumption of an individual in a population group is one liter. The Guides, however, apply to total intake from all sources. The upper limits of Range II correspond to the Radiation Protection Guide (RPG) for iodine–131 and to one-third of the RPG for radioactive strontium. The Guides are, for administrative reasons, expressed as a yearly radiation dose, but are based on lifetime exposure (*5*). The FRC emphasizes that the annual acceptable risk or exposure dose is not a dividing line between safety and danger in actual radiation situations (*6*).

Annual averages of radionuclide concentrations in milk sampled by the PHS Pastuerized Milk Network are presented in table 1. The data in table 1 are calculated as follows: Results from all samples collected in each week

29

(Sunday through Saturday) are averaged, and the averages for all weeks terminating in each of twelve consecutive months are averaged to obtain the annual average.[1] To obtain the annual average daily intake (pc/day) of radionuclides from milk, the annual average concentration values (pc/liter) in table 1 must be multiplied by the annual average daily consumption (liters/day) of milk.

Monthly variations of radionuclide concentrations in milk are influenced by a number of

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[1] Beginning with the October 1963 data, iodine-131 values of <10 pc/liter are considered to be zero for averaging purposes; previously, 5 pc/liter was used for calculating the averages.

TABLE 1.—MOVING ANNUAL AVERAGE RADIONUCLIDE CONCENTRATIONS IN MILK[a]

[Concentrations in pc/liter]

Sampling locations		Strontium-89		Strontium-90		Cesium-137	
		June 1963–May 1964	July 1963–June 1964	June 1963–May 1964	July 1963–June 1964	June 1963–May 1964	July 1963–June 1964
Ala:	Montgomery	21	14	23	23	91	91
Alaska:	Palmer	25	20	25	26	157	164
Ariz:	Phoenix	4	3	4	4	25	26
Ark:	Little Rock	47	31	47	46	167	157
Calif:	Sacramento	12	5	9	9	60	56
	San Francisco	16	8	12	11	69	65
Colo:	Denver	20	14	20	20	95	94
Conn:	Hartford	18	13	27	25	184	182
Del:	Wilmington	20	12	27	26	150	145
D. C:	Washington	24	15	20	20	106	99
Fla:	Tampa	12	9	15	15	241	246
Ga:	Atlanta	34	23	33	33	161	159
Hawaii:	Honolulu	10	6	11	11	83	83
Idaho:	Idaho Falls	43	27	31	30	187	189
Ill:	Chicago	16	10	21	21	130	128
Ind:	Indianapolis	18	13	24	23	112	110
Iowa:	Des Moines	35	19	28	27	101	98
Kans:	Wichita	30	14	23	23	81	75
Ky:	Louisville	50	30	36	35	122	113
La:	New Orleans	38	25	49	50	163	161
Maine:	Portland	24	19	34	35	235	242
Md:	Baltimore	33	19	23	23	133	123
Mass:	Boston	28	22	38	38	270	271
Mich:	Detroit	14	10	21	20	128	127
	Grand Rapids	15	11	23	22	137	138
Minn:	Minneapolis	44	27	35	35	171	168
Miss:	Jackson	36	26	40	41	120	120
Mo:	Kansas City	43	21	30	29	95	90
	St. Louis	31	17	26	24	96	93
Mont:	Helena	37	27	32	33	214	217
Nebr:	Omaha	34	21	28	28	109	106
Nev:	Las Vegas	12	10	11	12	84	87
N. H:	Manchester	25	19	37	36	288	286
N. J:	Trenton	17	12	22	21	141	137
N. Mex:	Albuquerque	13	8	12	12	56	56
N. Y:	Buffalo	18	13	24	23	161	161
	New York	27	19	32	32	194	193
	Syracuse	21	15	26	24	163	171
N. C:	Charlotte	39	25	35	35	134	129
N. Dak:	Minot	66	38	60	61	163	163
Ohio:	Cincinnati	21	14	27	26	105	104
	Cleveland	19	13	23	23	127	125
Okla:	Oklahoma City	28	16	24	24	89	82
Ore:	Portland	34	21	32	33	175	177
Pa:	Philadelphia	18	12	24	23	142	136
	Pittsburgh	27	18	32	32	174	171
P. R:	San Juan	17	11	13	13	85	80
R. I:	Providence	20	14	29	28	190	191
S. C:	Charleston	21	13	30	30	142	140
S. Dak:	Rapid City	52	35	45	45	174	169
Tenn:	Chattanooga	49	33	42	43	156	149
	Memphis	36	22	34	34	94	87
Tex:	Austin	11	7	10	10	49	47
	Dallas	21	12	21	21	81	76
Utah:	Salt Lake City	29	22	28	28	193	194
Vt:	Burlington	23	18	31	31	210	213
Va:	Norfolk	23	14	23	23	109	106
Wash:	Seattle	31	22	28	29	159	167
	Spokane	34	23	31	31	154	155
W. Va:	Charleston	40	26	31	30	108	102
Wis:	Milwaukee	15	10	21	20	142	143
Wyo:	Laramie	29	20	24	23	120	118
Network average		27	18	27.0	26.8	138	136

combined causes such as weather conditions and dairying practices. The moving yearly average (table 1), obtained by updating the previous twelve-month average by one month, shows variations averaged over the year and tends to minimize purely seasonal variations. This method, therefore, shows trends over a considerable period of time.

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RADIONUCLIDES IN INSTITUTIONAL DIET SAMPLES, JANUARY-MARCH 1964

Division of Radiological Health, Public Health Service

The determination of radionuclide concentrations in the diet constitutes an important element of an integrated program of environmental radiation surveillance and assessment. In recognition of the potential significance of the diet in contributing to total environmental radiation exposures, the Public Health Service initiated its Institutional Total Diet Sampling Network in 1961. This program is administered by the Division of Radiological Health with the assistance of the Division of Environmental Engineering and Food Protection (*1*).

The program is designed to estimate the dietary intake of radionuclides in a selected population group ranging from children to young adults of school age. Initially, the program consisted of sampling diets in eight institutions, but it has since been expanded to 23 boarding schools or institutions, geographically distributed as shown in figure 1. Institutions selected range from financially well-to-do boarding schools to orphanages with severe economic limitations. Each institution (sampling point), except those at Los Angeles, California, and Columbia, Mississippi, is located in a community from which the PHS Pasteurized Milk Network collects samples. The analytical data from the Pasteurized Milk Network supplement the findings for the Institutional Diet Sampling Program.

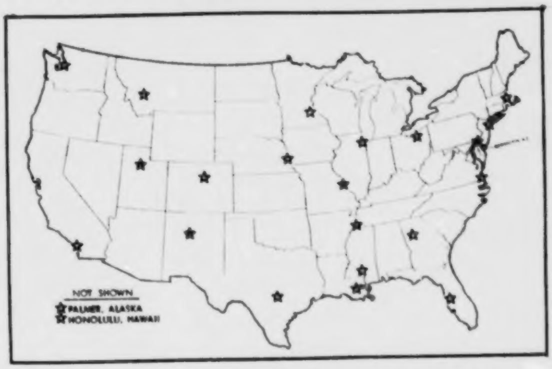

FIGURE 1.—INSTITUTIONAL DIET SAMPLING LOCATIONS

Sampling Procedure

In general, the sampling procedure is the same at each institution. Each sample represents the edible portion of the diet for a full 7-day week (21 meals plus soft drinks, candy bars, or other in-between snacks) obtained by duplicating the meals of a different individual each day. Each institution supplies one complete 7-day, 21-meal diet sample each month.

Each day's sample is kept frozen during the collection period. After collection, the total sample is packed in dry ice and shipped by air express to either the Southwestern Radiological Health Laboratory, Las Vegas, Nevada, the Southeastern Radiological Health Laboratory, Montgomery, Alabama, or the Northeastern Radiological Health Laboratory, Winchester, Massachusetts.

The sample for each day is packaged in three parts: (1) solid food and semi-solid foods minus those portions that would not ordinarily be eaten; (2) fluid milk; (3) other liquids such as soups, soft drinks, coffee, and tea. Drinking water from each station is analyzed routinely, but the data are not included in this report. A record of the contents of each meal and the approximate amount of each item is made at the institution and sent with the sample.

Analytical Procedures

Because calcium compounds may have an effect on the uptake of important bone-seeking radionuclides such as strontium-89 and strontium-90 (*2*), they are included in the analytical program. Total weight is accurately determined in the laboratory. Stable calcium and stable potassium determinations are obtained by conventional gravimetric or spectrophotometric methods. Samples usually range from 6 to 16 liters in volume and weigh from 8 to 20 kilograms.

The radioanalysis program is designed around three basic procedures: (1) gamma spectroscopy; (2) chemical separation of strontium-89 and strontium-90 with subsequent counting; and (3) radium-226 analysis. In the absence of interferences other than that from naturally-occurring radioactive potassium (K^{40}), minimum detectable concentrations for the gamma scan for iodine-131, cesium-137 and barium-140 are 10 pc/kg. Approximate minimum detectable concentrations for strontium-89, strontium-90 and radium-226 are: 5, 1 and 1 pc/kg, respectively. Since a constant weight of food is analyzed, the minimum detectable level on a per day basis (pc/day) will be dependent on the food intake.

Data

Table 1 gives the results of the laboratory analyses of the food samples in terms of concentrations of various radionuclides and stable elements, expressed as picocuries per kilogram of diet or grams per kilogram of diet, respectively.

Table 2 presents the dietary intake data expressed on a per-day basis from January through March 1964 for the 23 institutions from which samples were received. The intake values in this table were obtained by multiplying the food consumption in kg/day (column 4 of table 2) times the concentration values in grams or picocuries per kilogram of diet given in table 1. Also contained in the table is the range of ages of the children from which samples are being obtained. The reported radionuclide concentrations of these samples are extrapolated to the midpoint of the sample collection period.

Certain of the radioanalyses are reported by the laboratories as being "less-than" (<) a specified value. For data computations, the method employed is to use a zero for <10 pc/kg values for iodine-131 and barium-140. A 2.5 pc/kg was substituted for a <5 pc/kg of strontium-89; 0.5 was substituted for <1 pc/kg of radium-226.

The data are also presented graphically in figure 2 as a distribution of all sample values observed during the three months versus daily intake. The number of values reported during this quarter in each range is ploted as a frequency-distribution bar chart. The number of stations used in constructing these graphs was 22, 20, and 23 for the months of January, February, and March 1964, respectively. Therefore, the total number of samples represented in each distribution (a-e) is 65.

Discussion of Data

From table 2 it is apparent that the total intake ranged between 1.17 and 3.43 kg/day, with an average of 2.0 kg/day during this quarter. The frequency distribution bar chart (figure 2-a) shows that 48 samples, or 74 percent, weighed between 1.50 and 2.50 kg/day, inclusive.

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TABLE 1.—CONCENTRATION OF RADIONUCLIDES AND STABLE ELEMENTS IN INSTITUTIONAL DIETS, JANUARY-MARCH 1964 [a]

[Based on a 7-day composite sample]

Location of Institutions		Month (1964)	Calcium	Potassium	Radium-226	Strontium-89	Strontium-90	Cesium-137
			(grams per kilogram)		(picocuries per kilogram)			
Alaska:	Palmer	Jan	0.6	1.6	0.6	5	13	120
		Feb	0.7	1.8	0.7	10	17	135
		Mar	0.7	1.7	0.5	10	40	120
California:	Los Angeles	Jan	0.5	1.7	0.8	<5	6	65
		Feb	0.6	1.7	1.1	<5	8	70
		Mar	0.6	2.0	0.7	<5	14	50
Colorado:	Denver	Jan	0.6	1.6	0.6	5	11	65
		Feb	0.7	1.4	0.6	5	12	70
		Mar	0.6	1.4	0.5	<5	13	50
Delaware:	Wilmington	Jan	[b]—	—	—	—	—	—
		Feb	—	—	—	—	—	—
		Mar	0.7	1.6	0.3	<5	15	110
Florida:	Tampa	Jan	0.9	1.4	[e] 1.8	<5	15	225
		Feb	0.6	1.1	[e] 1.4	<5	15	130
		Mar	1.0	1.7	[e] 1.8	<5	14	105
Georgia:	Atlanta	Jan	0.4	1.0	[e] 0.6	5	13	60
		Feb	0.4	0.9	[e] 1.2	<5	16	55
		Mar	0.4	0.8	[e] 1.6	<5	11	55
Hawaii:	Honolulu	Jan	0.5	1.6	1.1	25	9	65
		Feb	0.5	1.6	1.8	5	12	70
		Mar	0.4	1.4	1.1	<5	10	75
Illinois:	Chicago	Jan	0.8	1.7	0.6	<5	15	120
		Feb	0.7	1.4	0.3	<5	16	110
		Mar	0.8	1.7	0.3	<5	15	120
Louisiana:	New Orleans	Jan	0.7	1.4	[e] 2.4	5	21	110
		Feb	0.6	1.5	[e] 2.5	5	26	140
		Mar	0.6	1.6	[e] 1.5	<5	31	140
Massachusetts:	Boston	Jan	0.8	1.6	0.2	10	23	215
		Feb	0.8	1.6	0.2	<5	26	200
		Mar	0.6	1.6	0.3	<5	19	170
Minnesota:	Minneapolis	Jan	0.4	1.6	0.5	<5	15	95
		Feb	0.5	1.6	0.8	<5	14	110
		Mar	0.5	1.5	0.5	10	19	110
Mississippi:	Columbia	Jan	0.8	1.4	[e] 3.1	<5	23	110
		Feb	0.8	1.4	[e] 2.6	5	25	120
		Mar	0.9	1.5	[e] 2.5	10	35	200
Missouri:	St. Louis	Jan	0.6	1.4	2.0	10	17	60
		Feb	0.7	1.6	0.7	10	33	75
		Mar	0.6	1.3	0.7	5	[illegible]	70
Montana:	Helena	Jan	0.5	1.2	0.5	<5	14	105
		Feb	0.5	1.2	0.4	<5	[illegible]	105
		Mar	0.6	0.9	0.3	10	27	110
Nebraska:	Omaha	Jan	0.7	1.5	0.4	<5	15	65
		Feb	0.7	1.5	0.4	<5	17	70
		Mar	0.8	1.5	[d]	<5	22	80
New Mexico:	Albuquerque	Jan	0.7	1.7	0.8	<5	14	45
		Feb	0.9	1.6	0.7	5	11	30
		Mar	0.9	1.4	0.4	<5	23	40
New York:	New York	Jan	1.0	1.7	0.3	<5	19	85
		Feb	[c]	[c]	[c]	[c]	[c]	[c]
		Mar	0.6	1.6	0.6	<5	16	115
Ohio:	Cleveland	Jan	0.5	1.7	0.6	<5	12	95
		Feb	0.7	1.7	0.6	<5	16	100
		Mar	0.6	1.7	0.3	<5	12	105
Tennessee:	Memphis	Jan	0.8	1.2	[e] 1.3	<5	22	65
		Feb	0.5	1.5	[e] 0.5	<5	12	55
		Mar	0.7	1.5	[e] 2.4	<5	20	65
Texas:	Austin	Jan	0.6	1.4	[e] 1.2	<5	9	45
		Feb	0.5	1.3	[e] 2.2	<5	10	45
		Mar	0.5	1.2	[e] 1.5	<5	10	30
Utah:	Salt Lake City	Jan	0.5	1.8	0.4	<5	12	135
		Feb	0.6	1.5	0.2	5	14	140
		Mar	0.6	1.6	0.4	<5	16	140
Virginia:	Norfolk	Jan	0.5	1.1	[e] 2.3	5	12	60
		Feb	0.5	1.2	[e] 1.5	5	13	60
		Mar	0.6	1.2	[e] 1.0	<5	11	60
Washington:	Seattle	Jan	0.6	1.5	0.7	<5	16	110
		Feb	0.6	1.4	0.8	5	14	90
		Mar	0.2	1.4	0.9	<5	16	100
Monthly average		Jan	0.6	1.5	[f] 0.7	<5	15	95
		Feb	0.6	1.5	[f] 0.7	<5	16	95
		Mar	0.6	1.5	[f] 0.5	<5	18	95

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[a] The monthly average iodine-131 and barium-140 concentrations were <10 pc/kg during this period. [b] Dash indicates station not in operation.
[e] Total radium values, not radium-226. [d] Indicates no analysis. [c] Indicates no sample. [f] Average for radium-226; does not include total radium.

TABLE 2.—INSTITUTIONAL DAILY DIETARY INTAKES (BASED ON A 7-DAY COMPOSITE SAMPLE), JANUARY-MARCH 1964 [a]

Location of Institutions		Age (years)	Month (1964)	Total Weight (kg/day)	Calcium	Potassium	Radium-226	Strontium-89	Strontium-90	Cesium-137
					(grams per day)		(picocuries per day)			
Alaska:	Palmer	6-16	Jan	1.57	0.9	2.5	1	10	20	190
			Feb	1.49	1.0	2.7	1	15	25	200
			Mar	1.25	0.9	2.1	1	10	50	150
California:	Los Angeles	12-18	Jan	2.02	1.0	3.4	2	5	12	130
			Feb	1.94	1.2	3.3	2	5	16	135
			Mar	1.44	0.9	2.9	1	5	20	70
Colorado:	Denver	4-17	Jan	2.63	1.6	4.2	2	15	29	170
			Feb	2.69	1.9	3.8	2	15	32	190
			Mar	3.10	1.9	4.3	2	10	40	155
Delaware:	Wilmington	6-14	Jan	[b]—	—	—	—	—	—	—
			Feb	—	—	—	—	—	—	—
			Mar	2.18	1.5	3.5	1	5	33	240
Florida:	Tampa	6-18	Jan	2.02	1.8	2.9	[c] 3.6	10	30	450
			Feb	2.88	1.8	3.0	[c] 4.0	10	44	375
			Mar	2.14	2.1	3.6	[c] 3.8	10	30	220
Georgia:	Atlanta	6-18	Jan	2.26	0.9	2.2	[c] 1.5	15	29	130
			Feb	2.39	1.0	2.3	[c] 2.9	5	38	130
			Mar	2.45	1.3	2.9	[c] 5.7	10	39	190
Hawaii:	Honolulu	7-20	Jan	1.90	1.0	3.0	2	50	17	125
			Feb	[d]—	—	—	—	—	—	—
			Mar	1.72	0.7	2.4	2	5	17	130
Illinois:	Chicago	6-15	Jan	1.17	1.0	2.0	1	0	17	135
			Feb	1.96	1.5	2.9	0	0	30	220
			Mar	1.76	1.3	2.9	0	0	26	215
Louisiana:	New Orleans	7-18	Jan	2.61	1.8	3.7	[c] 6.2	20	55	285
			Feb	2.65	1.7	4.0	[c] 6.4	20	69	370
			Mar	2.35	1.4	3.8	[c] 3.6	10	72	325
Massachusetts:	Boston	6-14	Jan	2.31	1.9	3.7	0	20	52	495
			Feb	1.48	1.2	2.5	0	5	38	300
			Mar	1.70	1.0	2.7	1	5	32	285
Minnesota:	Minneapolis	[e] <1-16	Jan	1.64	0.7	2.6	1	5	25	155
			Feb	1.61	0.8	2.6	1	5	23	175
			Mar	1.67	0.8	2.5	1	15	32	185
Mississippi:	Columbia	10-19	Jan	2.23	1.9	3.2	[c] 7.0	10	51	250
			Feb	1.81	1.4	2.5	[c] 4.7	10	46	215
			Mar	2.04	1.8	3.5	[c] 5.2	20	72	405
Missouri:	St. Louis	7-18	Jan	2.64	1.6	3.7	5	25	45	160
			Feb	2.49	1.7	4.0	2	25	82	185
			Mar	3.00	1.8	3.9	2	15	45	210
Montana:	Helena	6-17	Jan	2.60	1.3	3.1	1	5	36	275
			Feb	2.60	1.3	3.1	1	5	39	275
			Mar	2.20	1.3	2.0	1	20	59	240
Nebraska:	Omaha	8-18	Jan	2.09	1.5	3.1	1	5	31	135
			Feb	1.74	1.2	2.6	1	5	30	120
			Mar	2.40	1.9	3.6	[f]	5	53	190
New Mexico:	Albuquerque	5-15	Jan	2.04	1.4	3.5	2	5	29	90
			Feb	2.16	1.9	3.5	2	10	21	65
			Mar	2.00	1.8	2.8	1	5	46	80
New York:	New York	8-15	Jan	1.82	1.9	3.1	1	5	35	160
			Feb	[g]	[g]	[g]	[g]	[g]	[g]	[g]
			Mar	1.53	0.9	2.3	1	0	25	175
Ohio:	Cleveland	6-15	Jan	2.13	1.2	3.5	1	5	26	210
			Feb	2.32	1.5	4.0	1	5	35	230
			Mar	2.09	1.3	3.5	1	5	25	220
Tennessee:	Memphis	8-18	Jan	1.96	1.6	2.3	[c] 2.5	10	44	125
			Feb	1.82	0.8	2.7	[c] 1.0	5	22	100
			Mar	1.61	1.1	2.4	[c] 3.9	5	30	105
Texas:	Austin	6-19	Jan	1.79	1.0	2.4	[c] 2.2	5	16	80
			Feb	1.98	1.0	2.5	[c] 4.4	5	19	95
			Mar	1.96	0.9	2.4	[c] 3.0	5	19	65
Utah:	Salt Lake City	12-18	Jan	1.34	0.7	2.4	1.0	5	16	180
			Feb	1.50	0.9	2.2	0.0	10	21	210
			Mar	1.51	0.9	2.4	1.0	5	24	210
Virginia:	Norfolk	10-18	Jan	2.12	1.2	2.4	[c] 4.7	15	26	130
			Feb	2.00	1.0	2.4	[c] 3.1	10	28	120
			Mar	2.14	1.2	2.6	[c] 2.3	5	25	130
Washington:	Seattle	6-18	Jan	1.96	1.2	2.9	1.0	5	31	215
			Feb	1.92	1.2	2.7	2.0	10	27	175
			Mar	1.86	0.4	2.6	2.0	5	30	185
Monthly average			Jan	2.04	1.3	3.0	[h] 1.0	10	31	195
			Feb	2.07	1.3	3.0	[h] 1.0	10	34	195
			Mar	2.05	1.3	2.9	[h] 1.0	10	37	190

[a] Iodine-131 and barium-140 intakes at each institution were zero during this period. [b] Dash indicates station not in operation. [c] Total radium, not radium-226. [d] Sample weight unknown. [e] Food samples not collected for children too young for solid diets. [f] No analysis performed. [g] No sample available. [h] Average for radium-226; does not include total radium.

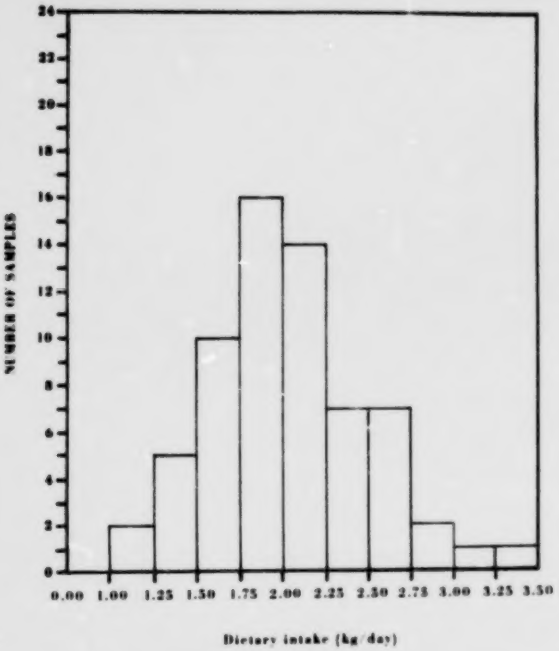

FIGURE 2-a.—DISTRIBUTION OF THE NUMBER OF SAMPLES VERSUS DIETARY INTAKE OF FOOD IN INSTITUTIONAL DIETS, JANUARY-MARCH 1964

The calcium intake (figure 2-b) ranged between 0.4 and 2.1 g/day, with 11 percent of the values being less than 0.8 g/day. Ninety-five percent of the samples analyzed for potassium (figure 2-c) showed that the intake was between 2.0 and 4.0 g/day.

Of the 43 samples analyzed for radium-226, only one intake value exceeded 2 pc/day; this was the St. Louis, Missouri sample for January, which contained 5 pc/day. The Federal Radiation Council (FRC) range II for radium-226 is 2 to 20 pc/day (*3*).

Strontium-89 intake averaged 10 pc/day during the first quarter. More samples contained nondetectable concentrations of strontium-89 during this quarter than in the previous one. Sixty-two sample results were 20 pc/day or less for strontium-89. Two results were 25 pc/day and one was 50 pc/day. For purposes of comparison the FRC range II for strontium-89 is 200 to 2000 pc/day (*3*).

The maximum strontium-90 intake (figure 2-d) during this quarter was 82 pc/day. Again for comparison, 75 percent of the values were between 10 and 40 pc/day. The average of all institutions increased from 31 pc/day in January to 37 pc/day in March. The FRC range II for strontium-90 is 20 to 200 pc/day (*3*).

Although the intake of cesium-137 (figure 2-e) ranged from 65 to 495 pc/day, the distribution shows a peak between 120 and 240 pc/day formed by 69 percent of the results. The average of all institutions is seen to have remained steady at 190 to 195 pc/day during the first three months in 1964.

Both barium-140 and iodine-131 were below the limits of detectability during this quarter.

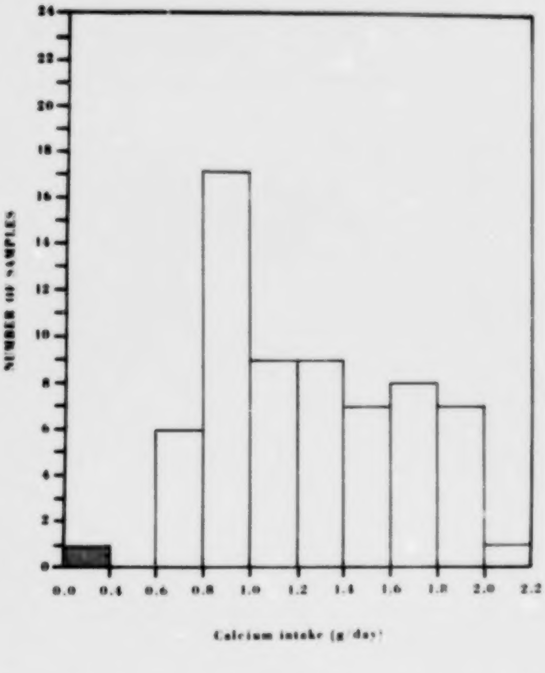

FIGURE 2-b.—DISTRIBUTION OF THE NUMBER OF SAMPLES VERSUS INTAKE OF CALCIUM IN INSTITUTIONAL DIETS, JANUARY-MARCH 1964

(Shaded portions show extended ranges)

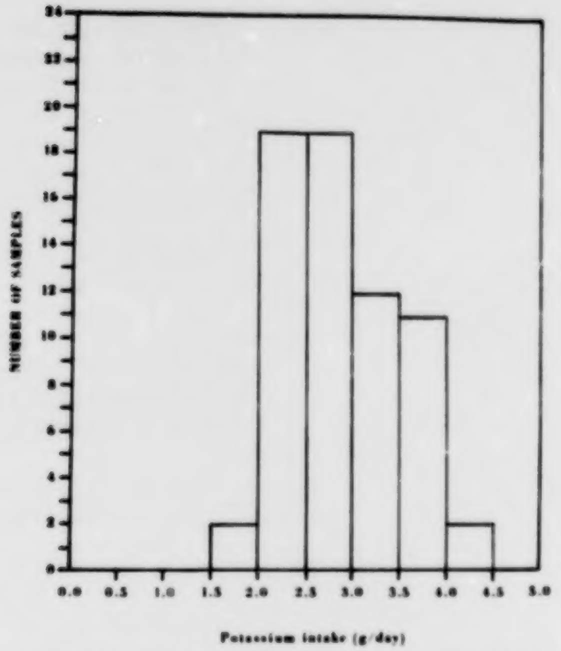

FIGURE 2-c.—DISTRIBUTION OF THE NUMBER OF SAMPLES VERSUS INTAKE OF POTASSIUM IN INSTITUTIONAL DIETS, JANUARY-MARCH 1964

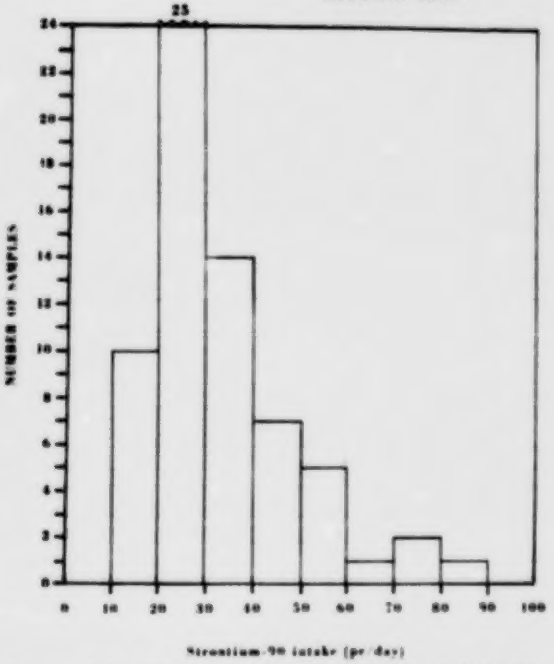

FIGURE 2-d.—DISTRIBUTION OF THE NUMBER OF SAMPLES VERSUS INTAKE OF STRONTIUM-90 IN INSTITUTIONAL DIETS, JANUARY-MARCH 1964

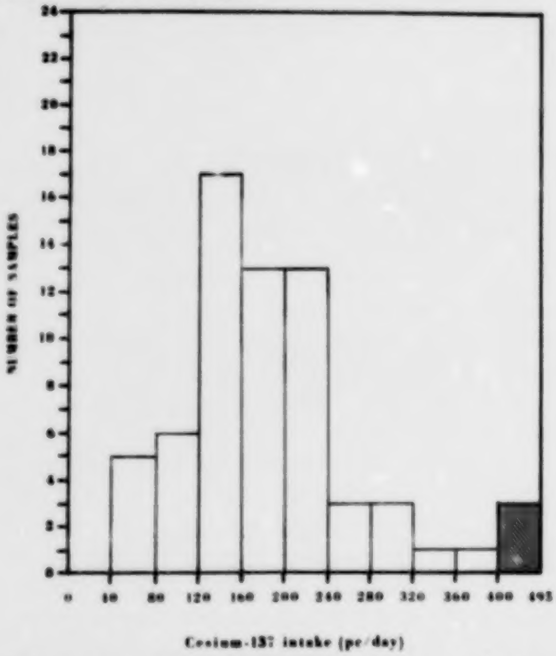

FIGURE 2-e.—DISTRIBUTION OF THE NUMBER OF SAMPLES VERSUS INTAKE OF CESIUM-137 IN INSTITUTIONAL DIETS, JANUARY-MARCH 1964
(Shaded portions show extended ranges)

3b

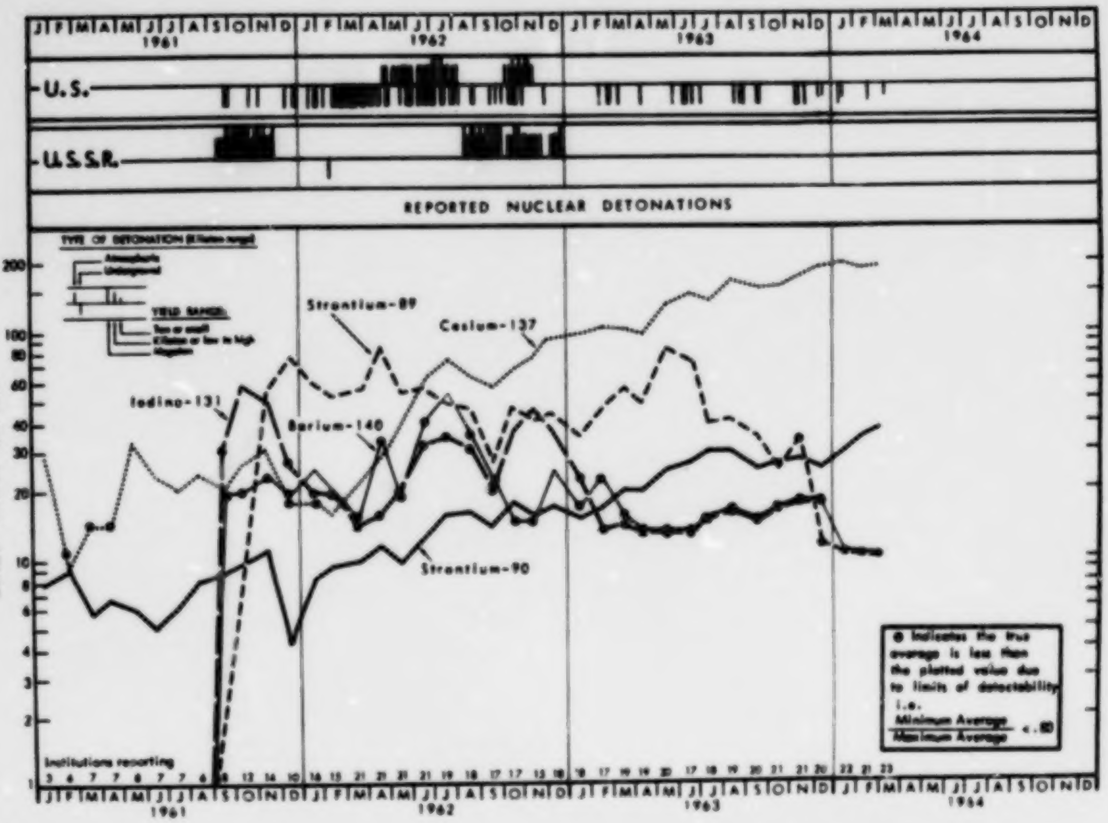

FIGURE 3.—RADIONUCLIDES IN INSTITUTIONAL DIET SAMPLES—AVERAGE OF INSTITUTIONS

REFERENCES

(*1*) Anderson, E. C., and D. J. Nelson, Jr.: Surveillance for Radiological Contamination in Foods, *American Journal of Public Health, 52:* 1391–400 (September 1962).

(*2*) Chen, P. S., Jr., A. R. Terepka, and H. C. Hodge: The Pharmacology and Toxicology of the Bone Seekers, *Annual Review of Pharmacology, 1:* 369–96 (1961).

(*3*) Federal Radiation Council: *Background Material for the Development of Radiation Protection Standards, Report No. 2,* Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402 (September 1961), price 20 cents.

Previous coverage in *Radiological Health Data:*

Period	Issue
July–September 1962	*April 1963*
October–December 1962	*July 1963*
January–March 1963	*September 1963*
April–June 1963	*December 1963*
July–September 1963	*March 1964*
October–December 1963	*July 1964*

Section III—Water

STRONTIUM-90 AND GROSS RADIOACTIVITY IN SURFACE WATERS OF THE UNITED STATES, APRIL 1964

Division of Water Supply and Pollution Control, Public Health Service

Levels of radioactivity in surface waters of the United States have been monitored by the Public Health Service Water Pollution Surveillance System since its initiation in 1957. Beginning with the establishment of 50 sampling points, this system has expanded to 130 stations as of September 1, 1964. These are operated jointly with other Federal, State, and local agencies, and industry. Samples are taken from surface waters of all major U. S. river basins for physical, chemical, biological and radiological analyses. These data can be used for evaluating sources of radioactivity which may affect specific domestic, commercial, and recreational uses of surface water. Further, the system provides background information necessary for recognizing pollution and water quality trends and for determining levels of radioactivity to which the population may be exposed. Data assembled through the system and exact locations of sampling points are published in annual compilations (*1–7*).

Sampling Procedures

The participating agencies collect one-liter "grab" samples each week and ship them "as is" to the Surveillance System Laboratory in Cincinnati for analysis. Gross alpha and gross beta radioactivity determinations on the suspended and dissolved solids are performed as frequently as deemed necessary.

Presently, gross alpha and beta determinations are made on monthly composites of the weekly samples received from most stations. Weekly analyses are conducted for stations located downstream from known potential sources of radioactive waste, as well as at all newly established stations for the first year of operation.

Normally, samples are counted within two weeks following collection or within one week after compositing. The decay of activity is followed on each sample for which the first analysis shows unusually high activity. Also, if a recount indicates that the original analysis was questionable, values based on recounting are recorded. All results are reported for the time of counting and are not extrapolated to the time of collection.

Analytical Methods

The analytical method used for determining gross alpha and beta radioactivity is described in the eleventh edition of "Standard Methods for the Examination of Water and Wastewater" (*8*). Suspended and dissolved solids are separated by passing the sample through

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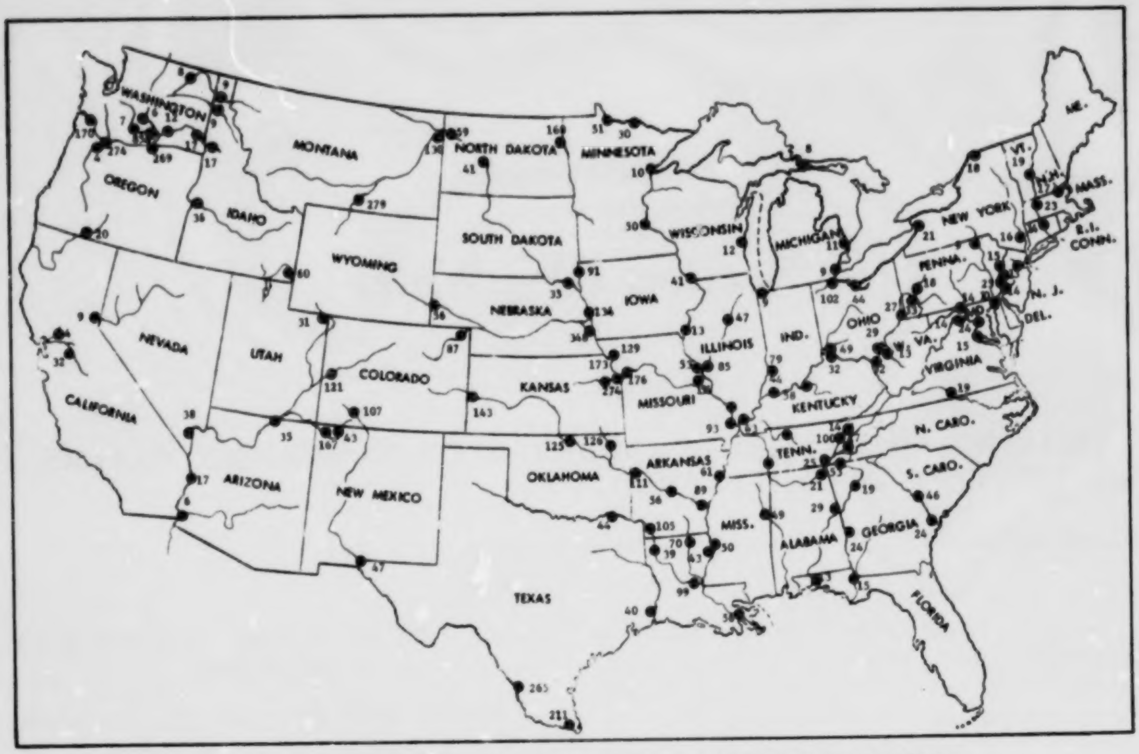
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CALIFORNIA
NEVADA
IDAHO
MONTANA
WYOMING
UTAH
ARIZONA
COLORADO
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
WISCONSIN
ILLINOIS
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MICHIGAN
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FIGURE 1.—TOTAL BETA ACTIVITY (pc/liter) IN SURFACE WATERS, APRIL 1964

a membrane filter (type HA) with a pore size of 0.45 micron. Planchets are then prepared for counting the dissolved solids (in the filtrate) and the suspended solids (on the charred membrane filter) in an internal proportional counter. Reference sources of U_3O_8, which give a known count rate if the instrument is in proper calibration, are used for daily checking of the counters.

Results

Table 1 presents April 1964 results of alpha and beta analyses of U. S. surface waters. The stations on a river are arranged in the table according to their relative location on the river, the first station listed being closest to the headwaters. These data are preliminary. Replicate analyses of some samples as well as some analyses incomplete at the time of this report will be included in the system's "Annual Compilation of Data" (*7*). The figures for gross alpha and gross beta radioactivity represent either determinations on composite samples or means of weekly determinations where composites were not made. The monthly means are reported to the nearest pc/liter. When all samples have zero pc/liter, the mean is reported as zero; when the calculated mean is between zero and 0.5 the mean is reported as <1 pc/liter.

A geographical perspective of the radioactivity in surface water is obtainable from the numbers printed near the stations as shown in figure 1, which gives the April 1964 average total beta activity in suspended-plus-dissolved solids in raw water collected at each station. Results for the years 1957–1962 have been summarized by Weaver *et al.* (*9*).

TABLE 1.—RADIOACTIVITY IN RAW SURFACE WATERS, APRIL 1964

[Average concentrations in pc/liter]

Station	Beta activity			Alpha activity		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Allegheny River:						
Pittsbugh, Pa	9	9	18	1	0	1
Animas River:						
Cedar Hill, N. Mex	27	16	43	6	2	8
Apalachicola River:						
Chattahoochee, Fla	6	9	15	0	0	0
Arkansas River:						
Coolidge, Kansas	52	91	143	2	21	23
Ponca City, Okla	92	33	125	10	5	15
Fort Smith, Ark	80	31	111	15	1	16
Little Rock, Ark	35	21	56	4	<1	4
Pendleton Ferry, Ark	63	26	89	6	0	6
Bear River:						
Preston, Idaho	4	56	60	0	0	0
Big Horn River:						
Hardin, Mont	243	36	279	38	20	58
Big Sioux River:						
Sioux Falls, S. Dak	18	73	91	0	2	2
Chattahoochee River:						
Atlanta, Ga	9	10	19	0	0	0
Columbus, Ga	15	9	24	1	0	0
Lanett, Ala	18	11	29	1	0	0
Chena River:						
Fairbanks, Alaska	0	3	3	0	0	0
Clearwater River:						
Lewiston, Idaho	6	11	17	0	0	0
Clinch River:						
Clinton, Tenn	4	10	14	0	<1	<1
Kingston, Tenn	15	85	100	0	0	0
Colorado River:						
Loma, Colo	89	32	121	11	6	17
Page, Ariz	1	34	35	0	9	9
Boulder City, Nev	3	35	38	0	14	14
Parker Dam, Calif-Ariz	1	16	17	0	4	4
Yuma, Ariz	0	6	6	0	6	6
Columbia River:						
Northport, Wash	0	8	8	0	1	1
Wenatchee, Wash	0	6	6	0	1	1
Pasco, Wash	162	692	854	0	1	1
McNary Dam, Ore	44	225	269	0	1	1
Bonneville, Ore	38	236	274	0	<1	<1
Clatskanie, Ore	25	145	170	0	0	0
Connecticut River:						
Wilder, Vt	6	13	19	0	0	0
Northfield, Mass	12	11	23	1	0	1
Enfield Dam, Conn	4	10	14	0	0	0
Cuyahoga River:						
Cleveland, Ohio	12	32	44	0	0	0
Delaware River:						
Martins Creek, Pa	5	10	15	0	0	0
Trenton, N. J	5	8	13	0	0	0
Philadelphia, Pa	14	11	25	1	1	2
Escambia River:						
Century, Fla	5	8	13	0	0	0
Great Lakes:						
Duluth, Minn	1	9	10	0	0	0
Sault Ste. Marie, Mich	2	6	8	0	0	0
Milwaukee, Wisc	3	9	12	0	0	0
Gary, Ind	1	8	9	0	0	0
Port Huron, Mich	2	9	11	0	0	0
Detroit, Mich	1	8	9	0	0	0
Buffalo, N. Y	6	15	21	0	0	0
Green River:						
Dutch John, Utah	2	29	31	0	4	4
Hudson River:						
Poughkeepsie, N. Y	3	13	16	0	0	0
Illinois River:						
Peoria, Ill	13	34	47	1	0	1
Grafton, Ill	24	29	53	2	1	3
Kanawha River: Winfield Dam, W. Va	6	7	13	0	0	0
Kansas River:						
De Soto, Kans	123	50	173	12	2	14
Klamath River:						
Keno, Ore	8	12	20	0	0	0
Little Miami River:						
Cincinnati, Ohio	21	28	49	2	1	3
Maumee River:						
Toledo, Ohio	64	38	102	3	0	3
Merrimack River:						
Lowell, Mass	6	11	17	0	0	0
Mississippi River:						
St. Paul, Minn	15	35	50	0	2	2
Dubuque, Iowa	19	22	41	1	1	2
Burlington, Iowa	12	1	13	1	0	1
E. St. Louis, Ill	57	28	85	3	0	3
Cape Girardeau, Mo	65	28	93	6	2	8
W. Memphis, Ark	44	17	61	2	0	2
Vicksburg, Miss	33	17	50	2	0	2
Delta, La	26	17	43	3	1	4
New Orleans, La	38	18	56	6	0	6
Missouri River:						
Williston, N. Dak	31	28	59	4	6	10
Bismarck, N. Dak	11	30	41	1	4	5
Yankton, S. Dak	4	29	33	0	4	4
Omaha, Nebr	104	30	134	17	4	21
St. Joseph, Mo	98	31	129	6	3	9
Kansas City, Kans	243	31	274	26	4	30
Missouri City, Mo	151	25	176	34	2	36
St. Louis, Mo	128	28	156	24	2	26
Monongahela River:						
Pittsburgh, Pa	26	7	33	4	0	4
North Platte River:						
Henry, Nebr	11	45	56	0	28	28
Ohio River:						
Toronto, Ohio	15	12	27	1	0	1
Addison, Ohio	18	11	29	1	0	1
Huntington, W. Va	41	11	52	3	0	3
Cincinnati, Ohio	18	14	32	1	0	1
Louisville, Ky	43	15	58	5	0	5
Evansville, Ind	31	13	44	3	0	3
Cairo, Ill	46	17	63	8	0	8
Ouachita River:						
Bastrop, La	44	26	70	5	1	6
Pend Oreille River:						
Albeni Falls Dam, Idaho	2	7	9	0	1	1
Platte River:						
Plattsmouth, Nebr	296	52	348	28	6	34
Potomac River:						
Williamsport, Md	7	7	14	0	0	0
Great Falls, Md	14	10	24	1	0	1
Washington, D.C	5	10	15	<1	<1	<1
Rainy River:						
Baudette, Minn	12	39	51	0	0	0
International Falls, Minn	4	26	30	0	1	1
Raritan River:						
Perth Amboy, N. J. (5 ft. Below Surface)	5	11	16	0	2	2
Perth Amboy, N. J. (5 ft. Above Bottom)	0	19	19	1	10	11
Red River, North:						
Grand Forks, N. Dak	105	63	168	5	0	5
Red River, South:						
Denison, Tex	1	43	44	0	2	2
Index, Ark	64	41	105	7	0	7
Bossier City, La	19	20	39	2	2	4
Alexandria, La	77	22	99	18	1	19
Rio Grande River:						
Alamosa, Colo	36	71	107	0	2	2
El Paso, Tex	25	22	47	3	2	5
Laredo, Tex	238	27	265	29	4	33
Brownsville, Tex	4	207	211	0	1	1
Roanoke River:						
John H. Kerr Resr/Dam, Va	9	10	19	0	0	0
Sabine River:						
Ruliff, Tex	16	24	40	1	1	2
Sacramento River:						
Greens Landing, Calif	0	4	4	0	0	0
St. Lawrence River:						
Massena, N. Y	4	14	18	0	0	0
San Joaquin River:						
Vernalis, Calif	8	24	32	1	7	8
San Juan River:						
Shiprock, N. Mex	129	38	167	14	13	27
Savannah River:						
North Augusta, S. C	29	17	46	2	0	2
Port Wentworth, Ga	9	15	24	<1	0	<1
Schuylkill River:						
Philadelphia, Pa	6	8	14	1	0	1
Shenandoah River:						
Berryville, Va	3	11	14	0	0	0
Ship Creek:						
Anchorage, Alaska	0	6	6	0	0	0
Snake River:						
Ice Harbor Dam, Wash	6	11	17	1	1	2
Wawawai, Wash	3	9	12	0	1	1
Payette, Idaho	20	16	36	3	4	7
South Platte River:						
Julesburg, Colo	10	77	87	1	56	57
Spokane River:						
Post Falls Dam, Idaho	2	7	9	0	0	0
Susquehanna River:						
Sayre, Pa	3	6	9	0	0	0
Conowingo, Md	4	6	10	1	0	1
Tennessee River:						
Lenoir City, Tenn	7	10	17	0	0	0
Chattanooga, Tenn	31	22	53	1	0	1
Bridgeport, Ala	10	11	21	1	0	1
Pickwick Landing, Tenn	9	16	25	1	0	1
Tombigbee River:						
Columbus, Miss	27	22	49	1	0	1
Truckee River:						
Farad, Calif	3	6	9	0	0	0
Verdigris River:						
Nowata, Okla	89	37	126	7	0	7
Wabash River:						
New Harmony, Ind	51	28	79	5	0	5
Willamette River:						
Portland, Ore	1	3	4	0	0	0
Yakima River:						
Richland, Wash	1	6	7	0	1	1
Yellowstone River:						
Sidney, Mont	108	22	130	17	4	21
Maximum	296	692	854	38	56	58
Minimum	0	1	3	0	0	0

Note: These data are preliminary; reanalysis of some samples may be made and additional analysis not completed at the time of the report may become available. For final data, one should consult the network's Annual Compilation of Data (7).

TABLE 2.—QUARTERLY AVERAGE STRONTIUM-90 CONCENTRATIONS IN SURFACE WATERS, APRIL 1963–MARCH 1964

[Concentrations in pc/liter]

Station	Apr.–June 1963	July–Sept. 1963	Oct.–Dec. 1963	Jan.–Mar. 1964
Allegheny River:				
Pittsburgh, Pa	1.8	[a]—	2.8	—
Animas River:				
Cedar Hill, N. Mex	—	1.8	—	1.7
Apalachicola River:				
Chattahoochee, Fla	—	2.9	—	1.5
Arkansas River:				
Coolidge, Kans	—	6.6	—	0.9
Ponca City, Okla	5.9	6.5	4.4	—
Fort Smith, Ark	—	6.7	—	3.5
Little Rock, Ark	—	4.8	4.4	—
Pendleton Ferry, Ark	5.5	—	4.3	—
Bear River:				
Preston, Idaho	—	3.7	—	1.1
Big Horn River:				
Hardin, Mont	5.8	—	2.3	—
Big Sioux River:				
Sioux Falls, S. Dak	—	9.5	5.0	2.8
Chattahoochee River:				
Atlanta, Ga	1.6	—	1.7	—
Columbus, Ga	1.5	—	1.7	—
Lanett, Ala	—	2.0	—	1.7
Chena Slough:				
Fairbanks, Alaska	0.7	—	0.2	—
Clearwater River:				
Lewiston, Idaho	—	1.2	—	0.8
Clinch River:				
Clinton, Tenn	—	1.4	—	2.0
Kingston, Tenn	5.6	9.4	6.5	7.5
Colorado River:				
Loma, Colo	2.5	—	1.4	—
Page, Ariz	—	4.2	—	5.9
Boulder City, Nev	1.8	—	1.5	—
Parker Dam, Calif-Ariz	—	1.0	—	1.9
Yuma, Ariz	0.9	—	1.1	—
Columbia River:				
Northport, Wash	—	3.4	—	1.5
Wenatchee, Wash	1.1	—	2.8	—
Pasco, Wash	2.4	2.7	3.4	3.1
McNary Dam, Ore	1.1	2.6	2.5	2.2
Bonneville, Ore	—	1.2	—	2.0
Clatskanie, Ore	1.3	2.5	1.6	—
Connecticut River:				
Wilder, Vt	—	2.6	—	1.3
Northfield, Mass	1.4	3.1	1.8	—
Enfield Dam, Conn	—	2.5	—	1.7
Cumberland River:				
Clarksville, Tenn	—	2.0	—	—
Cuyahoga River:				
Cleveland, Ohio	—	5.3	—	4.3
Delaware River:				
Martins Creek, Pa	1.7	—	1.6	—
Trenton, N. J	—	3.1	—	1.8
Philadelphia, Pa	1.1	—	2.1	—
Escambia River:				
Century, Fla	1.4	—	1.2	—
Great Lakes:				
Duluth, Minn	0.4	—	0.7	—
Sault Ste. Marie, Mich	—	1.5	—	0.8
Milwaukee, Wisc	0.8	—	0.8	—
Gary, Ind	—	1.6	—	1.2
Port Huron, Mich	1.3	—	1.2	—
Detroit, Mich	—	2.4	—	1.4
Buffalo, N. Y	2.2	—	2.5	—
Green River:				
Dutch John, Utah	—	2.7	—	4.6
Hudson River:				
Poughkeepsie, N. Y	3.8	—	5.0	—
Illinois River:				
Peoria, Ill	3.5	—	2.3	—
Grafton, Ill	—	4.4	—	3.8
Kanawha River:				
Winfield Dam, W. Va	—	2.9	—	1.1
Kansas River:				
De Soto, Kans	4.9	7.4	5.2	—
Klamath River:				
Keno, Ore	1.4	—	1.8	—
Little Miami River:				
Cincinnati, Ohio	—	5.3	1.4	3.3
Maumee River:				
Toledo, Ohio	4.9	—	2.7	—
Merrimack River:				
Lowell, Mass	—	1.6	—	1.8
Mississippi River:				
St. Paul, Minn	—	7.2	4.3	3.2
Dubuque, Iowa	4.2	—	3.7	—
Burlington, Iowa	—	7.3	4.3	2.8
E. St. Louis, Ill	4.0	—	3.8	—
Cape Girardeau, Mo	—	5.3	—	2.9
W. Memphis, Ark	3.6	—	3.6	—
Vicksburg, Miss	—	4.2	—	2.7
Delta, La	3.3	—	3.4	—
New Orleans, La	—	4.5	—	2.8
Missouri River:				
Williston, N. Dak	2.5	—	2.8	—
Bismarck, N. Dak	—	3.5	—	3.9
Yankton, S. Dak	3.3	—	3.3	—
Omaha, Nebr	—	4.5	—	3.3
St. Joseph, Mo	6.2	—	3.4	—
Kansas City, Kans	—	5.0	—	2.9
Missouri City, Mo	4.1	—	4.1	—
St. Louis, Mo	—	6.2	—	3.1
Monongahela River:				
Pittsburgh, Pa	2.7	3.3	3.3	—
North Platte River:				
Henry, Nebr	2.5	—	0.7	—
Ohio River:				
Toronto, Ohio	—	4.9	2.8	—
Addison, Ohio	—	4.0	—	2.2
Huntington, W. Va	1.9	—	3.0	—
Cincinnati, Ohio	—	3.7	—	1.6
Louisville, Ky	2.3	3.6	4.0	—
Evansville, Ind	—	4.2	—	2.5
Cairo, Ill	2.9	—	2.8	—
Ouachita River:				
Bastrop, La	—	4.5	—	3.0
Pend Oreille River:				
Albeni Falls Dam, Idaho	0.9	—	1.3	—
Platte River:				
Plattsmouth, Nebr	—	5.2	—	2.1
Potomac River:				
Williamsport, Md	1.4	—	1.7	—
Great Falls, Md	—	2.5	—	1.4
Washington, D. C	—	3.4	—	1.2
Rainy River:				
Baudette, Minn	2.5	4.7	4.1	—
International Falls, Minn	2.9	4.3	3.8	—
Red River, North:				
Grand Forks, N. Dak	—	11.3	7.1	4.9
Red River, South:				
Denison, Tex	—	5.6	—	5.8
Index, Ark	5.3	4.9	4.3	—
Bossier City, La	—	5.0	—	4.4
Alexandria, La	4.0	—	4.1	—
Rio Grande River:				
Alamosa, Colo	1.1	—	0.8	—
El Paso, Tex	—	1.9	—	0.6
Laredo, Tex	3.7	—	2.4	—
Brownsville, Tex	—	2.3	—	2.6
Roanoke River:				
John H. Kerr Resr/Dam, Va	1.3	—	2.6	—
Sabine River:				
Ruliff, Tex	—	3.2	—	2.5
Sacramento River:				
Courtland, Calif	—	1.4	1.0	1.0
St. Lawrence River:				
Massena, N. Y	—	2.3	—	1.6
San Joaquin River:				
Vernalis, Calif	1.3	—	1.5	—
San Juan River:				
Shiprock, N. Mex	1.9	—	2.1	—
Savannah River:				
North Augusta, So. Car	—	2.1	—	1.7
Port Wentworth, Ga	2.2	3.2	2.4	1.7
Schuylkill River:				
Philadelphia, Pa	—	3.7	—	1.4
Shenandoah River:				
Berryville, Va	1.2	—	1.0	—
Ship Creek:				
Anchorage, Alaska	—	0.9	—	0.4
Snake River:				
Ice Harbor Dam, Wash	—	1.3	—	1.0
Wawawai, Wash	0.9	—	0.7	—
Payette, Idaho	1.5	—	0.8	—
South Platte River:				
Julesburg, Colo	1.7	—	1.8	—
Spokane River:				
Post Falls, Idaho	—	1.2	—	1.3
Susquehanna River:				
Sayre, Pa	—	2.3	—	1.3
Conowingo, Md	1.6	—	3.0	—
Tennessee River:				
Lenoir City, Tenn	1.5	—	2.1	—
Chattanooga, Tenn	1.7	3.3	2.2	2.0
Bridgeport, Ala	1.6	—	2.2	—
Pickwick Landing, Tenn	—	2.5	—	2.1
Tombigbee River:				
Columbus, Miss	—	3.6	—	3.1
Truckee River:				
Farad, Calif	1.0	—	1.0	—
Verdigris River:				
Nowata, Okla	4.2	—	6.0	—
Wabash River:				
New Harmony, Ind	3.1	—	2.5	—
Willamette River:				
Portland, Ore	0.7	—	0.5	—
Yakima River:				
Richland, Wash	—	1.0	—	0.3
Yellowstone River:				
Sindey, Mont	—	5.0	—	1.9
Maximum	6.2	11.3	7.1	7.5
Minimum	0.4	0.9	0.2	0.3

[a] Dash indicates no sample collected.

Note: These data are preliminary; reanalysis of some samples may be made and additional analysis not completed at the time of the report may become available. For final data, one should consult the network's Annual Compilation of Data (7).

Strontium-90 Determinations and Results

Beginning in 1959, strontium-90 analyses of the total solids of surface waters were made quarterly on three-month composites of aliquots from weekly samples. Beginning in November 1962, the frequency of analysis was reduced to two quarterly samples per year at each sampling point except those stations immediately below nuclear installations, where quarterly analyses were continued. The method used for determining strontium-90 is a modification of a procedure described by Harley (*10*). The yttrium-90 together with an yttrium carrier is precipitated at pH 8.5; the precipitate is washed, redissolved, and reprecipitated as yttrium oxalate and the latter is washed and counted in a low-background anticoincidence, end-window proportional counter.

Table 2 presents the results of quarterly analyses of strontium-90 concentrations in U. S. surface waters for January-March 1964 as well as results for the previous three quarters for comparative purposes. The stations are arranged in the table according to their relative locations on the river, the first station being closest to the head-waters.

Floyd and Weaver summarized the strontium-90 results obtained from 1959 through 1963 in the August 1964 issue of *RHD* (*11*). During the January-March 1964 quarter, strontium-90 concentrations remained at about the same levels as were observed in the previous quarter. The average for the first quarter 1964 was 2.4 pc/liter, with values ranging from 0.3 to 7.5 pc/liter. While there are no standards for strontium-90 activity of total solids in surface water, the Public Health Service Drinking Water standards set the limit for strontium-90 concentrations in drinking water at 10 pc/liter (*12*). This limit for public water supplies is greater than the highest level observed during January-March 1964.

Discussion

The monthly dissolved beta activity averages exceeded 100 pc/liter only on the Columbia River and the Rio Grande. Of the six stations on the Columbia River, the four downstream from the Hanford Atomic Products Operations facility had averages of between 170 and 854 pc/liter. It can be observed that the concentration diminishes with distance downstream from the facility.

The dissolved alpha activity, which is associated with the dissolving of natural surface minerals by water, ranges in the monthly averages to 38 pc/liter. Of all stations, six on different rivers had monthly average dissolved alpha activity greater than 10 pc/liter.

While there are no generally applicable standards for surface waters, the radioactivity associated with dissolved solids provides a rough indication of the levels which could occur in treated water, since nearly all suspended matter is removed by the treatment process (*13*). The Public Health Service Drinking Water Standards state that in the absence of strontium-90 and alpha emitters,[1] a water supply is acceptable when the gross beta concentration does not exceed 1000 pc/liter (*12*).

REFERENCES

(*1*) Division of Water Supply and Pollution Control, Public Health Service: *National Water Quality Network Annual Compilation of Data, PHS Publication No. 663, 1958 Edition*, Superintendent of Documents, U. S. Government Printing Office, Washington D. C. 20402. Price $1.50.

(*2*) *Ibid.*, 1959 Edition. Price $1.75.

(*3*) *Ibid.*, 1960 Edition.[2]

(*4*) *Ibid.*, 1961 Edition.[2]

(*5*) *Ibid.*, 1962 Edition.[2]

(*6*) *Ibid.*, 1963 Edition (in press).

(*7*) *Ibid.*, 1964 Edition (to be published).

(*8*) American Public Health Association, American Water Works Association and Water Pollution Control Federation: *Standard Methods for the Examination of Water and Wastewater*, 11th Edition, New York (1960).

(*9*) Weaver, L., A. W. Hoadley, and S. Baker: Radioactivity in Surface Waters of the United States, 1957-1962. *Radiological Health Data*, 4: 306-16, (June 1963).

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[1] Absence is taken here to mean a negligibly small fraction of the specific limits of 3 pc/liter and 10 pc/liter for unidentified alpha emitters and strontium-90, respectively.

[2] Single free copies of this publication may be obtained from: Public Inquiries Branch, Public Health Service, U. S. Department of Health, Education, and Welfare, Washington, D. C. 20201.

(*10*) Harley, J. H.: Radiochemical Determinations of Strontium-90, *Health and Safety Laboratory Manual of Standard Procedures*, August 1962 Revision, Radiochemistry and Environmental Studies Division, HASL, U. S. Atomic Energy Commission, New York Operations Office (1962).

(*11*) Division of Water Supply and Pollution Control, Public Health Service: Radioactivity in Surface Waters of the United States, February 1964, *Radiological Health Data, 5:* 383–86 (August 1964).

(*12*) Public Health Service: *Drinking Water Standards, Revised 1962, Public Health Service Publication No. 956*, Superintendent of Documents, Government Printing Office, Washington, D. C. 20402 (March 1963), price 30 cents.

(*13*) Straub, C. P.: Significance of Radioactivity Data, *Journal of the American Water Works Association, 53:* 704 (June 1961).

Section IV—Other Data

PROGRESS IN DENTAL RADIOLOGICAL HEALTH

James W. Miller[1]

Medical and dental uses of radiation are the principal sources of man-made ionizing radiation to which the population of the United States is exposed. Diagnostic X-ray procedures account for almost all exposure from these sources (*1*). A review of the literature shows that prior to 1960 approximately 75 percent of the dental X-ray units in this country would not meet recommended standards; the major X-ray machine defects were unnecessarily large beams and insufficient filtration.

Of the more than 200,000 X-ray machines in use in this country, approximately 100,000 are owned and operated by dentists, exposing about 185,000,000 dental films a year. According to the U. S. National Health Survey, 49 million visits were made for dental X-rays during a 12-month period starting in July 1960 (*2*). On the average, an X-ray procedure was performed once in every five dental visits.

Since the major part of patient exposure in dentistry is from intra-oral roentgenography, many studies have been reported on the dose delivered (*3–14*). The values reported have usually been "air dose" measured at the tip of the cone, or "skin dose", that which strikes the patient's face. The "air dose" from a full-mouth survey of 14 films ranged from five roentgens to 315 roentgens, and the reported range of "skin dose" ranged from 1.5 roentgens to over 75 roentgens.

Patient gonadal dose incidental to intra-oral roentgenography depends on tube angulation, torso length, kilovoltage and beam diameter. Estimates of measured relative gonadal dose in adult males from dental X-ray procedures vary from 1/1000 to 1/10,000 of the "air dose" (*15–17*). Secondary and/or scattered radiation from the pointer cone, filter and patient's face has been shown to be the principal source of radiation to the reproductive organs from dental X-rays (*18*).

Reports of dermatitis and ulceration on the hands of dentists resulting from the practice of holding dental films in place during roentgenographic procedures have appeared in the literature. Young and Kunkel (*19*), reporting on 52 dentists who had developed X-ray dermatitis of the hands as a result of holding films, noted that 31 percent of these dentists, ranging in age from 34 to 66 (with an average age of 52), experienced malignant degeneration of such lesions. In a sample survey (*20*), the American Dental Association received a 9.5 percent affirmative reply to the question "Do you ever hold the film in the patient's mouth while the X-ray is being taken?" Another question in the survey was "Have you ever developed an X-ray burn on your fingers?", to which a total of 1.7 percent replied in the affirmative. No dentist under 30 years of age reported having had X-ray burns, but nearly 5 percent of dentists over 60 years of age admitted having had X-ray burns. Those with such burns had used dental roentgenographic equipment for an average of 14 years.

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Investigators have also reported large numbers of dental X-ray units which were operated in an unsafe manner, thereby subjecting dentists and ancillary personnel to unnecessary levels of exposure (*21–23*). Other studies, conducted in larger centers of population by interested parties and agencies following the 1956 report of the National Academy of Science, indicated that a large percentage of the dental X-ray machines in this country did not meet recommendations set forth by the National Committee on Radiation Protection and Measurements (*24*) or the recommendations of the American Academy of Oral Roentgenology (*25*).

Until about 1956, most of the radiation protection recommendations were made to protect occupationally exposed persons. Since that time, however, the need to control radiation exposure of the public has been widely emphasized. This awareness is evidenced by the rapidly expanding activities of the Division of Radiological Health, established in 1958 within the Public Health Service; the Federal Radiation Council, which was formed in 1959 to provide a Federal policy on human radiation exposure; and the enactment of specific legislation for radiation control activities by State and Federal agencies. The bulk of this legislative action for radiation control has taken place within the past four years. Because of legislative action and emphasis on this public health problem, most States are developing comprehensive radiation control programs.

Growth of Dental X-Ray Control Programs

A comprehensive radiological health program encompasses four principal areas: inspection, correction, education and research. Each is an integral part of a plan to attain the ultimate objective of eliminating unnecessary radiation exposure from dental sources.

Recognizing the need to provide assistance to health agencies in the planning, developing, and operating stages of their dental activities, the Division of Radiological Health in 1959 established the Dental X-Ray Program in its State Assistance Branch. This unit was assigned the responsibility of providing consultation, information, and other technical services to State and local health agencies in the development of sound dental radiological health programs. The objectives of this unit were to assist in the establishment of dental radiological health programs in all States and territories. The programs now in progress stress reduction of unnecessary exposure to patient and operator while attaining superior diagnostic quality of dental radiographs. Advice and assistance has been provided to health officers and State dental associations throughout the country, and thousands of Dental "Surpak" surveys have been made in most States.

Dental Surpak Surveys

Two survey techniques for the inspection of dental X-ray equipment are in general use. One method developed by the Public Health Service for conducting a large scale survey of dental X-ray machines is the "by mail" dental Surpak procedure, designed to assess the size of the beam at the end of the pointer cone, the approximate roentgen output, total filtration (inherent and added), beam symmetry, and leakage radiation in the direction of a patient's face. While this procedure assists materially in indicating the need for reducing patient and occupational exposure, it does not completely remove the need for installation inspections. The Surpak does serve, however, as an aid in surveying rural and inaccessible areas, locating and identifying machines needing priority attention, and as a method of followup after recommended improvements reportedly have been made.

A total of 58,000 Surpaks have been distributed by the Division of Radiological Health to 39 States as of June 30, 1964. Of the States that have used the Surpak, 27 have completed their initial survey in the sense that 65 to 95 percent of the dentists participated on a voluntary basis. Nationally, the mode is 80 percent voluntary participation. Results from 40,810 Surpaks returned by December 30, 1963 provided the beam diameter information in table 1. In an attempt to assess the progress in dental radiological health, the data were compiled by calendar year starting with 1960, the first year the Surpak was used in State programs.

Although results from different parts of the country varied by as much as 15 percent when the information was combined, a trend could be

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detected in the increase in the number of dental X-ray machines meeting present recommended standards. This trend is apparent in table 1.

TABLE 1.—BEAM DIAMETERS OF X-RAY MACHINES

[Percent]

Beam diameter (inches)	1960	1961	1962	1963
0–3.00	45.2	56.4	59.9	63.6
3.01 up	53.6	41.8	39.1	35.4
Unknown	1.2	1.8	1.0	1.0
Totals	100.0	100.0	100.0	100.0

Recommendations of the Public Health Service currently suggest that the beam diameter should be 2.75 inches at the tip of the cone regardless of length and shall not be greater than three inches. Using three inches as the maximum beam size, the proportion of machines not meeting this requirement dropped from 53.6 percent in 1960 to 35.4 percent for the year 1963, reflecting a substantial decrease in the dental contribution to radiation exposure.

Recommendations for total filtration of the useful beam are 1.5 mm. of aluminum equivalent for equipment capable of operating up to and including 70 kvp and 2.5 mm. total for those operating above 70 kvp. Even though the accuracy of the filtration determination by the surpak method is subject to some inherent errors, sufficient information is obtained to make a reasonable estimate in most cases. The unknown values in table 2 are the results of over-or underexposure of the surpak films, making it impossible to estimate the total filtration. Using 1.5 mm. of aluminum as the minimum amount of filtration required for dental X-ray machines regardless of kvp, we note an increase of 18 percent from 1960 to 1963 in number of machines meeting this minimum standard.

TABLE 2.—SURPAK RESULTS OF TOTAL FILTRATION

[Percent]

Filtration	1960	1961	1962	1963
<1.5	51.9	38.2	29.7	29.0
≥1.5	42.2	46.2	55.4	60.2
Unknown	5.9	15.6	14.9	10.8
Totals	100.0	100.0	100.0	100.0

By 1962, several States had progressed to a point in their program where the original Surpak data had been evaluated, and recommendations for correction were sent to the dentists. In most cases, the State health department sent corrective devices supplied by the Public Health Service to the dentist to bring the X-ray machine into compliance with established standards for filtration and collimation. After a period of time, a follow-up Surpak was sent to the dentist to determine whether the lead collimator and aluminum filters had been properly placed in the machine.

As a result of this type of follow-up program, 85.5 percent of the dental X-ray machines found to be below recommended standards for beam diameter at the time of the original survey were brought into compliance. Similar results were obtained in 1963. An 80-percent compliance from owners of X-ray machines originally found to be below standards has been achieved to date by this dental mail-order survey and correction method.

Physical Surveys

Another method of conducting a survey of dental X-ray machines is physical inspection of dental offices. The physical survey usually covers equipment, technique and occupational exposure. The method of inspection will vary with the established objectives of the X-ray program. There are, of course, many advantages to this type of survey. Defects in equipment can usually be corrected at the time of inspection. Another great advantage is the opportunity it provides for face-to-face education which often is very effective in accomplishing program objectives.

Of the 50 States that have instituted some type of inspection program, 11 conduct installation visits only; six use the Surpak only; and 33 States have or are using a combination of the Surpak with some other method, usually an installation inspection. The estimated number of dental X-ray machines surveyed by State or local health departments is conservatively set at 70,000. Although more inspections have been conducted, many have been duplications on the same dental X-ray machine.

At this time, the results of over 10,000 physical surveys of dental installations have been tabulated. The data regarding collimation and total filtration from these physical surveys, when compared with results of Surpak method, show a very close correlation in percentage meeting recommended standards at the time of the survey. After the survey, in a partial tabulation of results to date, 98 percent of the X-ray machines met the recommended standards for filtration, and 96 percent met the collimation requirement. Areas which will require additional attention, brought out by these surveys, are related to the techniques employed by the dentists. Further reduction of patient and operator exposure can be accomplished by using the fastest film available, although some changes of equipment and/or techniques are necessary to utilize this film. Strict attention to exposure time, development time, and temperature must be followed.

Scope of State Dental X-Ray Programs

Although every State has not been able to develop a comprehensive program up to this time, programs of inspection and correction of dental X-ray equipment and/or installations have been or are now being conducted in each of the 50 States. The majority of these inspection programs have been conducted on a voluntary rather than a regulatory basis. While regulations may be in effect, most health departments prefer to conduct cooperative voluntary programs with the dental profession.

Figure 1 shows the growth of State dental radiological health activities. As can be seen most program activity was noted between the years 1960 and 1964. The scope of these programs include a survey of the X-ray equipment with correction of existing defects and, where indicated, recommendation of changes in technique to further reduce radiation exposure.

These surveys also indicate that there is still a sizable amount of exposure (not necessary for the production of good diagnostic X-rays) that should be eliminated.

In a recent attempt to evaluate dental radiological health programs, information was obtained on the planned scope of the State's programs. This was separated into four categories, as presented in table 3. From this breakdown, it appears that many States have plans for a continuing program of inspection and correction.

TABLE 3.—PLANNED SCOPE OF STATE PROGRAMS [a]

Scope	Number of States [b]
Unknown	5
Inspection only	5
Inspection plus correction	15
Periodic inspection and correction	10
Continuous program of inspection, correction and education	17

[a] Data from 1962 status report (*26*).
[b] Includes Puerto Rico and District of Columbia.

It is generally agreed that a certain degree of educational effort will be necessary to obtain the ultimate objective of dental radiological health. This is especially true of those States whose programs have been on a voluntary, cooperative basis with the dental profession and in others on which only the condition of the equipment can be regulated.

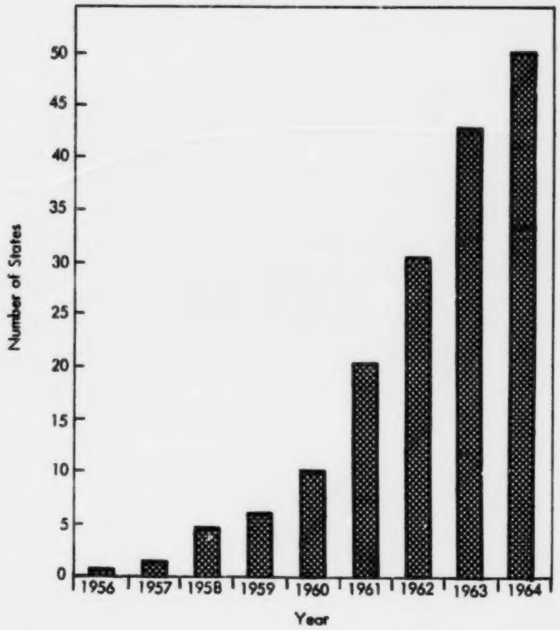

FIGURE 1.—STATES PARTICIPATING IN DENTAL RADIOLOGICAL HEALTH ACTIVITIES

In 1962, 34 States reported that they had already provided educational materials and programs on radiological health to the dental profession. Five other States indicated they were planning such programs. The long-range effectiveness of these educational efforts to date is difficult to assess. One method of evaluation might be the number of dental X-ray machines found in need of filtration or collimation. Based on such a method or on other survey findings, educational efforts employed by health agencies to date have not been too effective.

Ample information exists, however, which, if put into use, would enable a dental radiological health program to advance reasonably close to its ultimate objective of reducing radiation exposure to the minimum, consistent with good diagnostic radiography. The intensive inspection and correction programs putting into effect what is already known about X-ray equipment defects has been significantly successful in achieving modification of equipment to meet current recommended standards. Knowledge also exists on techniques which will further reduce patient and operator exposure from diagnostic radiography. It appears that future activities by health agencies must be directed to provide the dental profession with this specific knowledge about radiation and techniques which can further reduce exposure. This solution agrees with a statement by Scott (*27*) that "... the key to implementing the safe use and control of medical radiation lies in the education of all practicing physicians in the fundamentals of genetics, radiobiology and radiology." Many State health agencies have progressed to the point where their dental inspection and correction programs are limited to new installations and to a projected resurvey every two to five years. Now is the time to expand these programs and work with the universities and the profession by providing the undergraduate and the practicing dentist with the changing concepts and new knowledge in dental radiology.

Summary

Inspection and correction programs of dental X-ray equipment and/or installations have been or are now being conducted in each of the 50 States. Division of Radiological Health Surpak surveys of over 40,000 dental X-ray machines revealed that those meeting recommended standards for a beam diameter of three inches or less rose from 45.2 percent in 1960 to 64 percent in 1963. The percentage of those machines with 1.5 mm. or more of total aluminum filtration increased from 42.2 percent in 1960 to 60.2 percent in 1963.

Surveys also indicate that there is still a sizable potential for exposure reduction through the adoption of improved techniques that will not jeopardize the production of good diagnostic X-rays.

Correction of filtration and collimation defects have resulted in a substantial radiation decrease in the dental contribution to population exposure. However, educational means will be necessary to attain the ultimate objective of eliminating unnecessary radiation exposure.

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UTAH DENTAL X-RAY MACHINE SURVEY, 1961-1963

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As a part of Utah's program to eliminate unnecessary radiation exposure to all people involved directly or indirectly with X radiation, dental machines in the State were surveyed in 1961 by the dental Surpak survey method (*1*) and were resurveyed in 1962-63 by physical inspection at which time simple filtration and collimation defects were corrected by the surveyors. By the middle of February 1963, 432 dental installations with 455 X-ray machines were surveyed. The information obtained from these installations is the basis of this report. Several more have been surveyed since the compilation of the data. Three main areas were inspected during the physical survey: the X-ray machine itself; the exposing and developing of the film; and the exposure to personnel and patient. The present report summarizes the results of the 1962-63 physical survey and, where possible, attempts to draw comparisons with the 1961 Dental Surpak Survey.

Survey Procedures

Each machine was checked for: filtration, by noting the added filtration and using the inherent filtration listed by the manufacturer; collimation, with a fluorescent screen; roentgen output, using a Victoreen r-meter both before and after filtration was added; and other important factors including cord length, timer control, pointer cone, and tube head stability. The operational questions included the number of films per week, average exposure time, kvp and ma used, protective barriers and lead aprons for personnel and patients, personnel monitoring, type of film and developer, developing time and developer temperature. The third area of inspection was the operating position of the dentist and/or assistant. A water-filled plastic bottle, 5 inches in diameter and 8 inches tall, was used as a phantom to scatter the radiation in a manner similar to a patient's head. Measurements with a CS-40A "Cutie Pie" survey meter were taken where the X-ray personnel stood for right and left bitewing exposures and the anterior upper periapical exposure. Whenever it was felt that the exposure rate was higher than necessary or could be reduced, measurements were taken in new positions to find the lowest possible rate. The operators were informed of these new positions verbally. Individual letters summarizing all recommendations made during the survey were sent to each dentist after the survey.

Physical Characteristics of X-ray Machines

Filtration: The Public Health Service recommendations (*2*) for filtration were used on the survey. Two mm of aluminum equivalent filtration are suggested for dental machines operating at 70 kvp and less, and 2.5 mm for machines operating over 70 kvp. The inherent filtration of the X-ray machines was determined from the PHS information sheet entitled, "Dental X-ray Units—General Information" (*3*). Of all the X-ray machines surveyed, not including three cephalographic machines, 47 percent had their filtration deficiencies corrected during the survey. Two percent more needed corrections, but could not be corrected because either the pointer cone could not be removed or a special size filter was needed. The average addition was 0.9 mm of aluminum. Close to 52 percent of the 70 kvp machines and only 30 percent of the 90 kvp machines needed more filtration. This difference is probably due to the recent manufacture of the 90 kvp machines and the corresponding impact of Handbook 76 (4) on manufacturing design. The Surpak results showed that 23 percent of the 346 machines surveyed had two millimeters or more of filtration. The corresponding figures for the physical survey are 55 percent before modification and 98 percent after modification (see figure 1). The increased percentage of machines with 2 or more mm of filtration between the Surpak survey and the physical survey (32 percent) indicates that many dentists had their machines corrected after learning of their deficiencies from the State Health Department. The figure of 2 mm or more is used as a basis for comparison since there are no complete figures indicating the relationship between amount of filtration and the kvp in the Surpak results.

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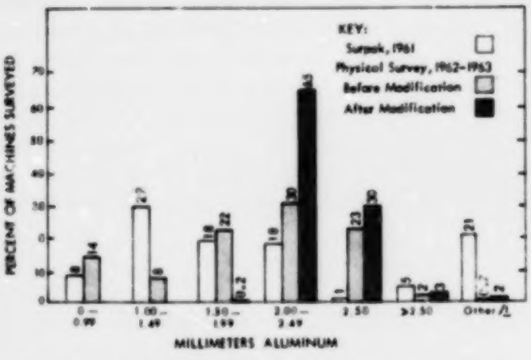

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FIGURE 1.—FILTRATION DISTRIBUTION

Collimation: The recommended X-ray beam diameter (2) of 2.75 inches was used as a goal for the survey. The lead collimators supplied by the Public Health Service for the most common dental machines were designed to give a beam diameter of 2.75 inches at the end of the pointer cone. Collimators were added to 20 percent of the machines during the survey (see figure 2). Only 1 percent more needed corrections which the surveyors were unable to make because they could not remove the pointer cone or did not have the proper size collimator. In many cases collimators were fabricated at the time of the survey or were placed in such a way as to correct the beam size of the machines for which there were no precut collimators. Less than 1 percent of the machines were left with beam diameters between 2.75 and 3.00 inches. They were left unchanged since they could not be corrected by the surveyors and caused very little excess exposure to the patients. The average beam size of those machines needing collimation was 3.7 inches (almost one inch too large), resulting in an area 80 percent larger than that of the recommended 2.75-inch beam. Thus, before modification, a total of 22 percent of the machines had beam diameters greater than 2.75 inches. Approximately 1 percent, although they had beams of 2.75 inches or less, were off-center. Additional filtration as well as collimation was needed in 15 percent of all the machines.

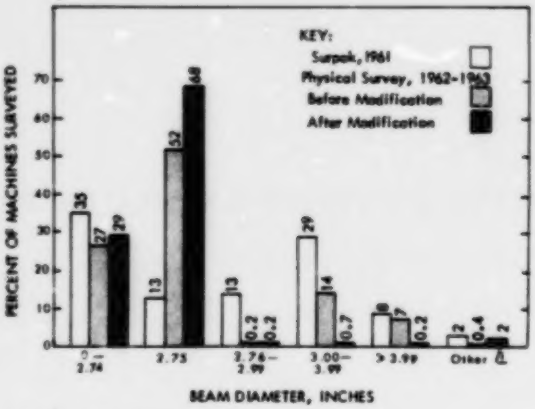

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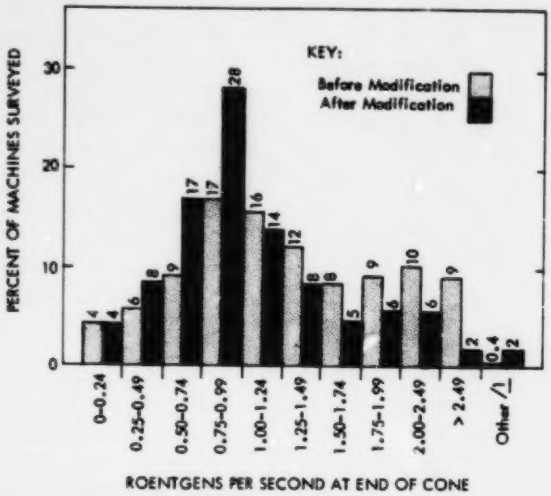
FIGURE 2.—BEAM DIAMETER DISTRIBUTION

The value of the Surpak survey is apparent from the improvements noted between the times of the surveys. While 48 percent of the machines surveyed by the Surpak method had beam diameters of 2.75 inches or less, 78 percent of the machines checked in the subsequent physical survey conformed to this standard.

Roentgen Output: The reduction in roentgen output per second at the end of the pointer cone, due to the filtration added during the survey, may be seen from table 1 and figure 3.

TABLE 1.—EFFECT OF FILTRATION ADDED DURING PHYSICAL SURVEY ON ROENTGEN OUTPUT

Output (r/sec)	Percent of machines surveyed	
	Before added filtration	After added filtration
less than 0.75	19	30
0.75–0.99	17	28
1 or more	64	42



/1 Unknown or could not be determined

FIGURE 3.—ROENTGEN OUTPUT DISTRIBUTION

Kilovoltage and Milliamperage: Of the machines surveyed, 76 percent were designed to operate around 70 kvp or less, while 24 percent were 90 kvp machines. In a few cases, the operators operated at about 70 kvp settings with 90 kvp machines. The most common milliamperages used were 10 ma (72 percent), and 15 ma (19 percent). Most variations from these milliamperages were minor.

Film Exposure and Development

Exposure Timer: Fifty-one percent of the X-ray machines had mechanical timers, while 49 percent had electrical timers. This percentage of mechanical timers is expected to decrease with time as more new machines replace the older ones, and electronic timers are substituted for the mechanical timers.

X-Ray Films: The grouping of the X-ray films used was done according to relative speed (*5*). The American Standards Association groups the film speeds into groups "A" through "F," with "F" being the fastest. Each film type is designated by the reciprocal of the exposure in roentgens required to produce a density of 1.0 under set conditions. Thus, low speed films have low numbers and the fast speed films have high numbers (*6*). From table 2, it can be seen that 43 percent of the operators used "B" speed group films and 55 percent used "C" or "D" films. The decrease in radiation exposure when going from group "B" to group "D" can be up to eight-fold. Therefore, the highest speed films should be used whenever possible in order to reduce unnecessary exposure to patients and personnel.

TABLE 2.—FILM SPEED DISTRIBUTION [a]

Speed group	Speed range (reciprocal roentgens)	Percent using film	Common films in group
A	1.5– 3.0	0.4	Rinn DC
B	3.0– 6.0	43	DuPont "D", Kodak Radia-tized, IFI BH 1, Rinn M.F.
C	6.0–12.0	15	IFI SDH 1, Minimax Intermediate, Rinn E.F.
D	12.0–24.0	40	DuPont "LF", Kodak Ultra-Speed, Minimax Extra Fast, Rinn S.F.
E	24.0–48.0	0	Rinn H.F.
F	48.0–96.0	0	None
—	Unknown	1.5	

[a] Film characteristics from reference (5).

Darkroom Procedure: In many installations, the darkroom procedure left much to be desired. The surveyors found that the dentists usually had their assistants develop the films. Generally the assistants had had no training in proper developing techniques, but had received a few comments or instructions from the dentist or previous assistants on the overall procedure. The most common mistake was a long exposure time and a short development time—"to save time." This procedure greatly increases the radiation exposure to the patient and personnel while saving only two or three minutes. It is felt that in most cases, the dentist could be continuing his examination or work on the patient during the lengthened developing period with no waste of time or inconvenience to him or the patient.

Two-thirds (66 percent) of the installations used thermometers in the developer, 3 percent had thermometers but did not use them, and 31 percent had no thermometer. Table 3 lists the reported usual temperature of the developer.

It is assumed that the developing solutions reported to be at room temperatures were in the 65°-75° F. range. Therefore, 97 percent were in the 65°-75° F. range.

TABLE 3.—DEVELOPING TEMPERATURES USED (° F)

	60-64	65-67	68	69-75	Room temperature	76-78
Number	8	26	166	101	150	4
Percent	2	6	36	22	33	1

When considering the development time distribution, it should be noted that many of those interviewed merely estimated the time, since they used the "sight" method instead of a timer. This involves checking the film by sight against a red light during development to obtain the best picture, which often leads to overexposure and under-development. The film and developer solution manufacturers recommend 3.5 minutes as the minimum and 5 minutes as the optimum time for the film to be in the developer when its temperature is 68° F. However, 54 percent of the installations reported less than 3.5 minutes, 35 percent more than 3.5 minutes, and 11 percent used the sight method, which is generally shorter than 3.5 minutes. It should be noted that more than half of the installations did not use 68° F., and therefore should have used a different developing time. It appears evident that most of the installations did not use the optimum time, and many used less than the minimum recommended time.

Less than half (45 percent) completely changed the developer every 4 weeks or less, 61 percent changed every 6 weeks or less and 2 percent changed the solution after 20 weeks or more. The longest period between changes was 6 months. However, many replenished the solution between changes. There were 20 percent who changed solutions only when the films were not developing properly or the solution had evaporated and oxidized. Many of those giving the number of weeks between changes were averaging or guessing in that they changed solutions when the quality of the films necessitated, rather than on a fixed schedule. Only 39 percent of the darkrooms were light-tight; that is, no outside light could be seen in the darkroom.

Exposure to Patients and Personnel

The reduction of radiation exposure to the operating personnel as well as the patients was of primary importance in the survey. To obtain exposure figures on operating personnel, readings were taken at normal operating positions and at other possible operating positions until one of minimal exposure was found. Also, the presence of protective barriers, lead aprons for patient and operator, personnel monitoring, exposure per film, and length of timer cord were noted. Of the timer cords used, 78 percent were 6 feet or longer while 22 percent were less than 6 feet long. Often a cord shorter than 6 feet was adequate in the presence of shielding.

Personnel Monitoring: Personnel monitoring was not used in any form by 57 percent, 8 percent used film badges, 1 percent used pocket dosimeters and 34 percent used dental films with a paper clip or coin attached. Thus, 43 percent of the dentists had used, or were using, some sort of personnel monitoring while in their present offices. The 9 percent who used film badges or pocket dosimeters always registered below 25 milliroentgens per week. Sometimes a slight image had been found on dental film badges, but these were considered inconclusive since the film had often been used for several weeks at a time and had been placed in the X-ray room, rather than on the personnel. After considering the personnel monitoring results, the maximum exposure rate of personnel (see below), and the workloads found in this survey, it would appear that there is little reason for careful personnel monitoring (see Handbook 76 (4)), except in the cases where the operator holds films, stands next to the patient, has a large workload, or wants to be sure he is getting very little exposure.

Number of Films Per Week: Of the dentists involved with the X-ray machines surveyed, 63 percent used less than 50 films (exposures) per week per machine (see figure 4). The qualification of number of films per machine should

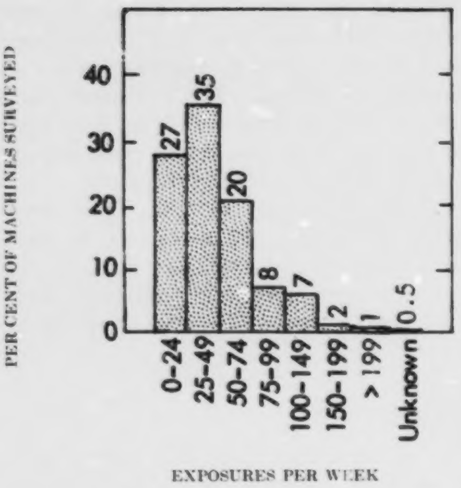


FIGURE 4.—DISTRIBUTION OF EXPOSURES PER WEEK

be noted, since 5 percent of the dentists had more than one X-ray machine.

Milliampere-Seconds Per Week: The total milliampere-seconds per week were obtained by multiplying the films per week by the product of the calculated average exposure time per film and the usual milliamperes used (see figure 5). Of all machines, 36 percent had less than 200 mas/wk., 53 percent had less than 300 mas/wk., 80 percent had less than 700 mas/wk., and 97 percent had less than 2000 mas/wk. The highest workload was 3180 mas/wk.

Maximum Exposure Rate of Personnel: The average maximum exposure rate for operators standing in the positions they normally used prior to the survey was 260 milliroentgens per hour, whereas the average maximum rate when standing in the new positions recommended as a result of the survey was 5.7 milliroentgens per hour, a reduction of 98 percent. For assistants, the corresponding values were 145 milliroentgens per hour and 5.2 milliroentgens per hour, a reduction of 97 percent. The readings taken at the positions normally used prior to the survey were made after recommended modifications to the machines had been completed; therefore, these readings are probably lower than the actual exposures of operators prior to the survey.

Protective Lead Shields: Only 15 percent of the installations had lead shields of one type or another; 7 percent had fixed shields with no window, 4 percent had mobile shields with leaded window, and 2 percent had fixed shields with leaded window. Only 16 percent had lead aprons, and 14 percent had lead aprons for the patient only, while 1 percent had aprons for both the operator and patient. Many of these with aprons used them only on pregnant women for full mouth X-ray series, or when requested. The use of leaded aprons during every X-ray exposure of each patient in or below the reproductive age was strongly recommended.

Skin Exposure per Film: The calculated average time per film was multiplied by the roentgen output per second to determine the average skin exposure per film. This was done using roentgen outputs both before and after filtration modification. The after-modification figures may be in error. If the dentist had 1.5 mm. filtration added and had good exposure and developing techniques before the survey, he might have had to increase his exposure time to get a clear film. This then would place the after-modification skin exposure per film used here in the report lower than the true figure. However, in most cases the exposing

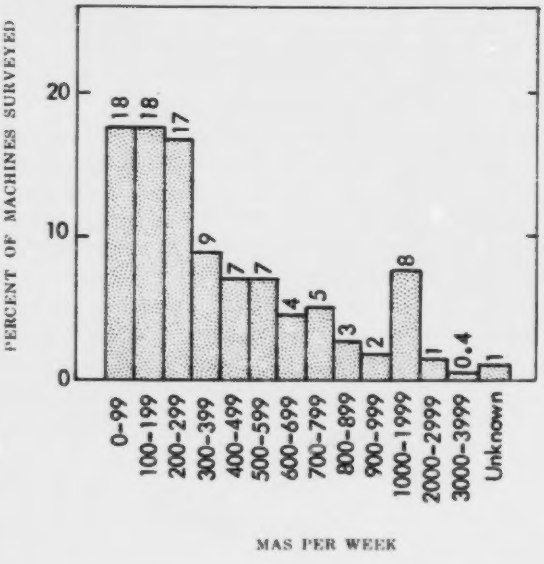


FIGURE 5.—MILLIAMPERE-SECONDS PER WEEK DISTRIBUTION

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and developing techniques were not good—the exposure time was longer than necessary and the developing time was too short. Therefore, if the dentist used proper techniques after the survey (including faster film in some cases), the skin exposure per film used here could be greater than the true figure. Since these two possible effects tend to counterbalance each other, the latter effect being more probable, the figures used here should be approximately correct and probably somewhat conservative.

The reduction of the skin exposure per film may be seen in the following table. The reduction of the average exposure is 35 percent. One case was observed with a low value of 0.03 r/film. However, it is believed that a mistake may have been made in the recording of this value on the survey form. Therefore this figure is not shown on the following table.

TABLE 4.—SKIN EXPOSURE PER FILM

[Roentgens]

	Before modification	After modification
Maximum	8.99	4.05
Minimum	0.09	0.09
Average	1.32	0.88

The percentage less than 1.0 r/film was 55 before modification and 66 after modification.

Conclusions

It is felt that the physical survey was very worthwhile from the standpoint of the reduction of unnecessary radiation exposure. The earlier Surpak survey informed the dentists of some deficiencies in their machines and brought their attention to radiation exposure in general, resulting in some corrections being made. The physical survey covered a much larger portion of the diagnostic X-ray procedures and thus was able to accomplish more toward reducing unnecessary exposure. The correction of filtration and collimation during the survey helped a great deal, but large reductions of personnel and patient exposure were also brought about by procedural changes and the alteration of operating positions. It is emphasized that the reduction in potential exposures will be achieved only to the degree that the recommendations are followed. However, the response of dentists and assistants, in the vast majority of cases, strongly indicated an appreciation of the problems indicated and an equally strong tendency to follow recommendations.

Acknowledgements

The cooperation of the Industrial Commission of Utah, all local health departments in the State, the Utah State Medical Association, the Utah State Dental Association and the Utah State Radiological Society are gratefully acknowledged.

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STRONTIUM-90 IN HUMAN VERTEBRAE, 1962-1963[1]

Joseph Rivera[2]

Since March of 1961, samples of human vertebrae have been obtained by the Health and Safety Laboratory (HASL) for strontium-90 analyses. The specimens are from accident victims who lived in New York City, Chicago, and San Francisco prior to death. Results of the analyses of specimens obtained during 1963 are presented in table 1 and for comparative purposes results obtained from the analyses of 1962 samples are presented in table 2. The results of the analyses of samples from San Juan will be reported in the near future. In each case it has been assumed that the calcium content of vertebrae was 0.37 g Ca/g ash, since this was the average result found from the analyses of over 115 samples (standard deviation ±0.02 g/g ash).

On the average, the Sr^{90} content of vertebrae at each age was highest in New York City and lowest in San Francisco. This result is the same as that found for samples collected during 1961 and 1962, and is to be expected from the estimated dietary intakes of Sr^{90} at the three cities since 1960.

As in the previous years, the variation of Sr^{90}/Ca ratios with age was similar to that found by Kulp *et al.* (*1*) and other investigators. Highest strontium-90 concentrations were found in the bones of children under 1 year of age at death and lowest concentrations were found in the bones of individuals more than 20 years of age. There was also an indication of increased bone Sr^{90} concentrations during adolescence.

As compared with 1962, the 1963 average Sr^{90} concentrations of human vertebrae were higher for both children and adults. This result was also expected, since average dietary Sr^{90} levels during 1963 were higher than 1962.

Since the Sr^{90} content of the diet was increasing rapidly during the year, data on the Sr^{90} content of bone were tabulated as average values for each age, during both halves of 1963. The observed bone Sr^{90} concentrations were, on the average, higher for each age during the second half of the year than the first. The differences were particularly great for the youngest individuals, whose rate of bone formation was presumably higher than that of older people.

The Sr^{90} content of adult vertebrae containing one gram of calcium can be given by the following expression (*2*):

where: $X_n = X_{n-1} - f X_{n-1} + f K Z$,

X_n is the concentration of Sr^{90} for year 'n',
X_{n-1} is the concentration of Sr^{90} for year 'n—1',
f is the fraction of the bone Sr^{90} exchanged during the year,
K is the diet-bone observed ratio,
and Z is the Sr^{90}/Ca in the diet during the year.

In this equation all of the variables are known except 'f'. The HASL Tri-City diet studies yield estimates of Z for the three cities; X_n and X_{n-1} are given in tables 1 and 2 (>20 year old); and K has been established by numerous studies to be about 0.25 (*3*). Solving for 'f' and inserting the appropriate values for the other variables leaves:

$$f = \frac{X_n - X_{n-1}}{KZ - X_{n-1}}$$

$$f = \frac{1.55 - 0.90}{(.25)\,(30) - 0.90} = \frac{0.65}{6.60} = 0.10 \qquad \text{(New York City)}$$

$$f = \frac{1.11 - 0.79}{(.25)\,(19) - 0.79} = \frac{0.32}{3.96} = 0.08 \qquad \text{(Chicago)}$$

$$f = \frac{0.94 - 0.66}{(.25)\,(14) - 0.66} = \frac{0.28}{2.84} = 0.10 \qquad \text{(San Francisco)}$$

These results are in excellent agreement with the previously estimated value of 9 percent annual turnover for strontium in adult human vertebrae (*4*).

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[1] Summarized from the Atomic Energy Commission's *Fallout Program Quarterly Summary Report, HASL-146:* 236–40, Office of Technical Services, Department of Commerce, Washington, D. C. 20230 (July 1964) price $3.50.

[2] Mr. Rivera is a physicist on the staff of Environmental Studies Division of the Health and Safety Laboratory, U. S. Atomic Energy Commission, New York, N. Y. 10014.

TABLE 1.—STRONTIUM-90 IN HUMAN VERTEBRAE, 1963

[Concentrations in pc/g Ca]

Age at death	New York City			Chicago			San Francisco		
	First half [a]	Second half [b]	All 1963	First half [a]	Second half [b]	All 1963	First half [a]	Second half [b]	All 1963
0-1	—	6.81 [c] (10)	6.81 (10)	—	3.51 (2)	3.51 (2)	1.31 (11)	2.43 (21)	2.04 (32)
1-2	3.49 [c] (1)	9.84 (1)	6.66 (2)	—	—	—	2.72 (2)	—	2.72 (2)
2-3	2.44 (3)	5.03 (3)	3.73 (6)	—	3.70 (2)	3.70 (2)	1.40 (6)	3.51 (1)	1.70 (7)
3-4	1.54 (1)	3.41 (2)	2.79 (3)	—	2.76 (3)	2.76 (3)	1.13 (5)	—	1.13 (5)
4-5	2.22 (1)	—	2.22 (1)	—	—	—	1.64 (2)	1.72 (3)	1.69 (5)
5-6	1.87 (2)	3.46 (1)	2.40 (3)	—	2.10 (1)	2.10 (1)	—	2.37 (3)	2.37 (3)
6-7	1.83 (2)	2.11 (1)	1.92 (3)	—	—	—	1.24 (1)	—	1.24 (1)
7-8	—	—	—	—	—	—	1.00 (1)	1.63 (3)	1.47 (4)
8-9	1.89 (4)	—	1.89 (4)	—	—	—	0.82 (2)	—	0.82 (2)
9-10	—	1.62 (1)	1.62 (1)	—	—	—	—	2.05 (1)	2.05 (1)
10-12	1.35 (1)	2.84 (1)	2.10 (2)	—	—	—	0.89 (1)	1.91 (2)	1.57 (3)
12-14	—	2.59 (1)	2.59 (1)	—	2.73 (1)	2.73 (1)	1.00 (1)	1.31 (4)	1.25 (5)
14-16	1.22 (1)	2.92 (1)	2.07 (2)	—	—	—	1.17 (1)	—	1.17 (1)
16-18	2.00 (4)	2.23 (2)	1.70 (6)	—	—	—	1.20 (3)	1.43 (2)	1.29 (5)
18-20	1.82 (2)	2.04 (2)	1.93 (4)	1.32 (1)	—	1.32 (1)	0.92 (1)	0.32 (1)	0.62 (2)
20-40	2.16 (1)	1.51 (11)	1.56 (12)	0.74 (2)	1.01 (4)	0.92 (6)	0.73 (3)	1.00 (11)	0.94 (14)
40-60	0.95 (1)	1.58 (5)	1.48 (6)	—	1.24 (4)	1.24 (4)	0.66 (2)	0.97 (4)	0.87 (6)
>60	—	1.61 (5)	1.61 (5)	—	1.43 (2)	1.43 (2)	—	1.21 (2)	1.21 (2)
0-4	2.47 (5)	6.24 (16)	5.34 (21)	—	3.24 (7)	3.24 (7)	1.41 (24)	2.48 (22)	1.92 (46)
4-20	1.85 (17)	2.41 (10)	1.97 (27)	1.32 (1)	2.41 (2)	2.05 (3)	1.13 (13)	1.66 (19)	1.44 (32)
>20	1.55 (2)	1.55 (21)	1.55 (23)	0.74 (2)	1.19 (10)	1.11 (12)	0.70 (5)	1.02 (17)	0.94 (22)

[a] Deceased January 1, 1963-June 30, 1963.
[b] Deceased July 1, 1963-December 31, 1963.
[c] Values in parentheses indicate number of samples.

A principle objective of the HASL bone sampling program is to see how well bone Sr^{90} concentrations can be predicted from diet Sr^{90} estimates. The data presented in this report indicate that:

1. The absolute levels of Sr^{90} in bone specimens collected in New York City, Chicago and San Francisco are proportional to the dietary Sr^{90}/Ca ratios estimated from the HASL Tri-City diet studies.

2. The variation of Sr^{90} levels in bone with time parallels the variations in Sr^{90} intake with time as estimated from the HASL Tri-City Diet studies.

3. Calculations of strontium turnover rates in human adult vertebrae, using observed bone levels and estimated dietary intakes, are consistent among the three cities.

TABLE 2.—STRONTIUM-90 IN HUMAN VERTEBRAE, 1962

[Concentrations in pc/g Ca]

Age at death	New York City			Chicago			San Francisco		
	First half [a]	Second half [b]	All 1962	First half [a]	Second half [b]	All 1962	First half [a]	Second half [b]	All 1962
0-1	4.03 [c] (3)	3.58 (11)	3.68 (14)	1.40 (1)	—	1.40 (1)	1.24 (5)	0.99 (16)	1.05 (21)
1-2	2.83 (3)	4.24 (2)	3.39 (5)	—	2.32 (1)	2.32 (1)	1.03 (2)	0.90 (2)	0.95 (4)
2-3	2.11 (1)	2.87 (4)	2.72 (5)	—	—	—	0.77 (2)	1.54 (4)	1.28 (6)
3-4	2.28 (3)	2.78 (6)	2.61 (9)	0.68 (1)	—	0.68 (1)	1.18 (2)	1.49 (1)	1.22 (3)
4-5	2.03 (3)	—	2.03 (3)	0.96 (2)	—	0.96 (2)	1.92 (2)	0.76 (1)	1.53 (3)
5-6	—	—	—	1.89 (1)	1.46 (1)	1.68 (2)	0.65 (2)	0.57 (1)	0.62 (3)
6-7	1.54 (2)	2.86 (1)	1.98 (3)	1.49 (1)	—	1.49 (1)	1.25 (1)	1.03 (2)	1.10 (3)
7-8	1.83 (2)	1.65 (1)	1.77 (3)	—	—	—	0.97 (2)	—	0.97 (2)
8-9	—	1.67 (5)	1.67 (5)	—	—	—	—	—	—
9-10	0.89 (1)	1.46 (1)	1.18 (2)	1.43 (1)	—	1.43 (1)	—	0.51 (1)	0.51 (1)
10-12	1.55 (1)	—	1.55 (1)	1.10 (3)	—	1.10 (3)	0.53 (2)	—	0.53 (2)
12-14	1.13 (2)	1.93 (3)	1.61 (5)	0.73 (1)	1.43 (1)	1.08 (2)	1.20 (1)	—	1.20 (1)
14-16	1.32 (6)	—	1.32 (6)	1.27 (1)	1.78 (1)	1.53 (2)	1.28 (2)	0.97 (1)	1.18 (3)
16-18	1.34 (2)	1.98 (3)	1.72 (5)	—	1.51 (1)	1.51 (1)	—	1.10 (1)	1.10 (1)
18-20	1.31 (2)	2.05 (2)	1.68 (4)	0.76 (1)	—	0.76 (1)	—	0.97 (4)	0.97 (4)
20-40	0.66 (3)	1.32 (2)	0.92 (5)	0.54 (11)	1.22 (7)	0.80 (18)	0.96 (2)	0.92 (3)	0.94 (5)
40-60	0.50 (2)	0.91 (2)	0.70 (4)	0.63 (29)	0.90 (6)	0.68 (35)	—	0.54 (4)	0.54 (4)
> 60	1.02 (3)	1.08 (2)	1.04 (5)	1.47 (5)	0.94 (1)	1.38 (6)	—	0.59 (11)	0.59 (11)
0-4	2.95 (10)	3.31 (23)	3.20 (33)	1.04 (2)	2.32 (1)	1.47 (3)	1.10 (11)	1.10 (23)	1.10 (33)
4-20	1.46 (21)	1.88 (16)	1.64 (37)	1.16 (11)	1.55 (4)	1.26 (15)	1.10 (12)	0.90 (11)	1.00 (23)
> 20	0.76 (8)	1.10 (6)	0.90 (14)	0.70 (45)	1.06 (14)	0.79 (59)	0.96 (2)	0.63 (18)	0.66 (20)

[a] Deceased January 1, 1962-June 30, 1962.
[b] Deceased July 1, 1962-December 31, 1962.
[c] Values in parentheses indicate number of samples.

The conclusions therefore reached are that the HASL Tri-City estimates do represent fairly accurately the actual average Sr^{90} intake at the respective cities, and that the Sr^{90} content of adult vertebrae can be calculated using these diet estimates, a turnover rate of 9 percent per year and a diet-bone observed ratio of 0.25.

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ENVIRONMENTAL LEVELS OF RADIOACTIVITY AT ATOMIC ENERGY COMMISSION INSTALLATIONS

The U. S. Atomic Energy Commission receives from its contractors semi-annual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant perimeter surveys are required.

Summaries of the environmental radioactivity data for 23 AEC installations have appeared periodically in *RHD* since November 1960. Summaries follow for Lawrence Radiation Laboratory sites and the Los Alamos Scientific Laboratory.

1. Lawrence Radiation Laboratory
Calendar Year 1963

University of California
Berkeley, California

Berkeley Site

The Berkeley site of the Lawrence Radiation Laboratory (LRL) is located to the east of the campus of the University of California (see figure 1). Technical facilities include a 6.3 Bev proton accelerator (Bevatron), a 700 Mev cyclotron, a linear accelerator of 10 Mev per nucleon, 88-inch cyclotron, and various chemistry and physics laboratories.

The environmental sampling program includes monitoring of the atmosphere, water and rain or dry deposition. Three types of atmospheric samples are taken: stack samples, local area samples, and perimeter samples. Data for these are shown in table 1.

TABLE 1.—ATMOSPHERIC MONITORING, BERKELEY SITE 1963

[Average concentrations in pc/m³]

Sampling location	Total No. of samples	First half		Second half	
		Alpha	Beta	Alpha	Beta
Stacks	5,460	0.006	3.10	0.005	2.90
Local area	510	0.001	8.50	0.001	2.79
Perimeter	206	0.001	9.58	0.001	3.14

Approximately 75 "stacks", mostly laboratory hoods and glove box exhausts, are being sampled. These represent the greatest potential for releasing activity. One-inch-diameter filters are used at flow rate of one liter per minute. The filters are changed weekly and counted for beta activity by an end-window Geiger-Mueller tube and for alpha activity by a zinc sulfide scintillation detector. Limits of detection for an individual stack sample were 0.10 pc/m³ alpha and 2.3 pc/m³ beta. Local area and perimeter air samples are taken on outdoor areas on the Laboratory site and at the property line, respectively. The samples are taken on 4″ x 9″ HV–70 filter paper at 4 cfm. The filters are changed weekly and are counted for alpha activity by a large area gas flow proportional counter and for beta activity by two Geiger-Mueller tubes, with 30 mg/cm² window. A 40 percent loss in the alpha count is assumed for self absorption. Limits of detection were 0.15 pc/m³ beta and 0.005 pc/m³ alpha.

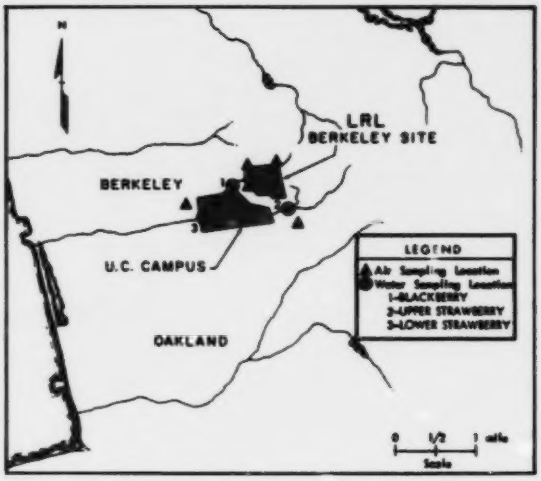

FIGURE 1.—ENVIRONMENTAL SAMPLING LOCATIONS AT THE BERKELEY SITE

Rain or deposition samples are collected in 18-inch-diameter cylindrical vessels lined with polyethylene bags at local area and perimeter sites. Deposition data are given in table 2. At two remote locations in Berkeley and Oakland, samples are collected in small rain gauges. The bag is changed monthly at all stations. Rain samples are poured out and evaporated in beakers. If the bag is dry, it is rinsed out with dilute nitric acid which is then evaporated. Final evaporation is in 2" diameter stainless steel planchets which are then flamed and coated with a thin film of lacquer. These planchets are counted for alpha activity in an internal flow proportional counter and for beta activity with a thin window low background Geiger-Mueller flow counter. No correction is made for self-absorption in the sample. Detection limits vary, depending on the size of the sample and length of time counted.

TABLE 2.—TOTAL DEPOSITION, BERKELEY SITE, LAST HALF 1963

[Average concentrations in nc/m²]

Location	Number of samples	Alpha	Beta
Local area	57	0.09	40.54
Perimeter	24	0.15	60.23

Water samples are taken from laboratory wastes, onsite streams and offsite streams. The laboratory waste is sampled at two buildings designated by numbers 70 and 71. At building 70, a continuous sample is collected from the acid waste system for weekly analyses. This represents about one-fourth of the total Laboratory discharge to the sewer. Samples of approximately two liters each are acidified, evaporated and counted in the same manner as rain samples. Detection limits vary but were no greater than 0.4 pc/liter alpha and 1 pc/liter beta.

Waste from laboratory areas in building 71 is retained in 350-gallon holding tanks until analyzed. A one-quart sample is taken from each tank and is handled and counted in the same manner as samples taken at Building 70.

Surface water on the Laboratory site drains into two small streams which merge into one at the lower end of the University campus. One side stream (Upper Strawberry) and the final combined stream (Lower Strawberry) are sampled biweekly; the other side stream (Blackberry) is sampled weekly. Six nearby offsite creeks are also sampled. The four nearest ones are sampled bi-weekly, the other two more remote ones every four weeks. One-quart samples are taken in each case and handled in the same way as rain samples. The sampling stations are shown in figure 1. Results for all water samples are shown in table 3.

TABLE 3.—WATER MONITORING, BERKELEY SITE, 1963

[Average concentrations in pc/liter]

Type of sample	Total No. of samples	First half		Second half	
		Alpha	Beta	Alpha	Beta
Sewage	123	0.20	22.2	0.28	132
Tap water	53	0.05	21.4	0.14	16.6
Onsite streams	156	0.64	44.9	2.05	20.8
Offsite streams	104	0.32	13.3	0.80	4.7

Livermore Site

The Livermore site of LRL is located three miles east of Livermore, California (see figure 2). Technical facilities include a small cyclotron, a two-megawatt swimming pool reactor, and physics and chemistry programs associated with a weapons development program.

An environmental sampling program is maintained to provide information regarding the effectiveness of control measures and to determine whether any radiological changes in the environment are the result of laboratory operations. The sampling program includes air particulates, soil, domestic water, sewer effluent and sewage plant products. Air samples were collected to ascertain that control efforts are restricting the release of radioactivity from the Laboratory to levels which do not exceed the permissible levels for the neighborhood around an atomic energy facility. The water samples were collected to monitor radioactivity in an underground water supply which is the sole source of domestic water for the cities of Livermore and Pleasanton.

Air samples are collected continuously at 11 sites within 5 miles of the LRL. The 4" x 9" HV-70 sampling papers are changed after seven days of sampling at a rate of 4 cfm. A minimum decay period of 96 hours was observed before the papers were counted to eliminate the effect of natural radon and thoron daughters. The alpha activity remaining was

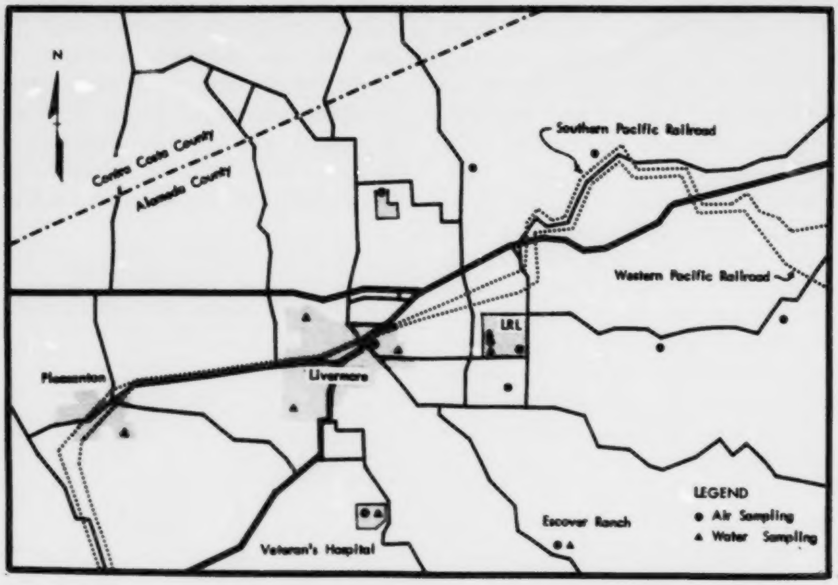

FIGURE 2.—SAMPLING LOCATIONS AT THE LIVERMORE SITE

measured with a counter equipped with a zinc sulfide scintillation detector with a counting efficiency of about 30 percent. The beta activity was measured with a Geiger-Mueller tube with a counting efficiency of about 13 percent. The standards of comparison used were 0.04 pc/m^3 for alpha and 10 pc/m^3 for beta as recommended in NBS handbook No. 69. The limit of sensitivity was 0.00073 pc/m^3 for alpha and 0.0059 pc/m^3 for beta. Average results for the eleven air sampling stations, which collected 800 samples at Livermore in 1963 were 0.0025 pc/m^3 alpha and 2.33 pc/m^3 beta. The alpha average concentration was about half of that of 1962 and the beta was 2.33 pc/m^3 for 1963 compared to 2.1 for 1962.

Domestic water samples were collected monthly from two onsite wells and six nearby areas to insure that radioactivity from Laboratory operations is not entering the underground water supply which provides most of the drinking water for Livermore and Pleasanton, and all of the water for ranches in the valley. The average radionuclide concentration in all of the domestic water samples was below the limit of sensitivity for alpha (8.9 pc/liter) and for beta (41 pc/liter). The standards of comparison used were 10 pc/liter for alpha and 600 pc/liter beta as recommended in NBS handbok 69. The gas proportional counter used in these measurements had a counting efficiency of 36 percent for alpha and 31 percent for beta emitters.

Samples of top layer soil were collected quarterly at the 19 sampling stations surrounding the Livermore Site. The alpha activity was below the limit of sensitivity—50 pc/g—for all the samples. The beta activity averaged 44 pc/g. This concentration was less than the 1962 average of 100 pc/g.

Continuous sampling is maintained at the sewer line leaving the southwest project boundary where it connects with the Livermore domestic sewer lines. As a back up to the sewer effluent sampling program, grab samples were collected monthly at the Livermore Sewage Disposal Plant to establish that liquid effluent from the laboratory is not creating abnormal radioactivity concentrations in the oxidation ponds and dried sludge. The sludge is used as an agricultural soil conditioner and the oxidation ponds overflow into a natural waterway. The results for effluent monitoring at Livermore 1963 are summarized in table 4.

TABLE 4.—EFFLUENT MONITORING, LIVERMORE SITE, 1963

[Average concentrations in pc/liter]

Type of sample	Number of samples	First half		Second half	
		Alpha	Beta	Alpha	Beta
Sewer effluent	130	6.1	130	6.3	130
Oxidation pond	15	9.2	145		
Sewage plant (pc/gm)	39	6.7	46		

Note: Standard of comparison (alpha + beta) 300.

A program for the measurement of low level "background" radiation was initiated in February 1963. Standard personnel film was used for the first five months, then fluoroglass dosimeters were used after June to integrate the external "background" radiation. Thirteen dosimeters were placed at strategic locations on the security fence approximately four feet above ground and three dosimeters were placed at offsite ranches. The dosimeters were left in the field for six months. The external radiation dose was less than 50 mr for 1963, the limit of detectability, at the Laboratory perimeter and at the offsite locations. Therefore, the external radiation dose rate at the Laboratory perimeter was approximately 0.01 mr/hr, essentially natural background.

Site 300

Site 300 is part of the LRL operation at Livermore. The site is located in a very sparsely populated ranching area about 17 miles southeast of LRL at Livermore. Air and water samples are taken to determine whether operations at Site 300 are changing the normal concentrations in the vicinity. Lack of power facilities necessitated installation of most of the air samplers within the boundaries of the site. All the water samples were taken from wells located on the site because they are the only readily accessible source of underground water in the area. All samples, air and water, are processed at LRL, Livermore.

Air sampling was on a continuous basis at seven stations, and the filter papers were changed three times per week. The standards of comparison for alpha are 1 pc/m^3 for the onsite stations and 0.1 pc/m^3 for the offsite station located at Tracy, eight miles northeast of Site 300. The standards for beta are 1,000 pc/m^3 onsite and 100 pc/m^3 offsite. Average results for all air station samples combined are shown in table 5.

Soil and water samples were collected once per month at both on and offsite locations. Only top layer soil was collected to determine fallout concentrations. Onsite wells, the only domestic water sources for the site, were sampled monthly whereas offsite streams were sampled only during the winter months when water flow existed. The average soil and water concentrations for the past year are summarized in table 5. The standards of comparison for alpha are 6,000 pc/liter for onsite locations and 600 pc/liter for offsite locations. For beta emitters, the standards are 30,000 pc/liter for onsite locations and 3,000 pc/liter for offsite locations.

Previous coverage in *Radiological Health Data:*

Period	Issue
Fourth Quarter 1960 and First Half 1961	*March 1962*
Second Half 1961	*October 1962*
Calendar Year 1962	*October 1963*

TABLE 5.—ENVIRONMENTAL SAMPLING, SITE 300, 1963

[Average concentrations in pc/m^3]

Type of sample	Number of stations	First half			Second half		
		Number of samples	Alpha	Beta	Number of samples	Alpha	Beta
Air (pc/m^3)	7	858	0.0028	3.0	430	0023	2.0
Soil (pc/g)	9	90	<5	45		5	40
Onsite wells (pc/liter)	6	69	<8.9	<41			
Offsite streams	3	11	<8.9	<41			

2. Los Alamos Scientific Laboratory, 1962-1963

University of California
Los Alamos, New Mexico

As part of the environmental monitoring program at Los Alamos, measurements of air particulate radioactivity, activity in precipitation and gamma background are made periodically. The samples were taken on the roof of building TA–50 (about 1¾ mile S.E. of the Administrative Building, the former location) starting in March 1963. Gamma background surveys were discontinued in March 1963.

Air Monitoring

Airborne radioactive particulate matter is collected on 4-inch-diameter filters. The sampling rate was reduced from 46 m^3/hr in 1962 to 25.5 m^3/hr in 1963, due to the addition of an activated charcoal filter behind the first filter. Air samples are ordinarily collected for 24 hour intervals during the work week; 72-hour weekend samples are collected.

The filters are counted for beta activity 7 days after collection in a thin-window (methane) flow proportional counter, with an over-all efficiency for Sr^{90}–Y^{90} of 50 percent. Results are tabulated in table 6 and show a decrease in beta activity in 1963 over that of 1962. The MPC value for beta in air is 100 pc/m^3 as stated in NBS Handbook No. 69.

Table 6.—BETA ACTIVITY OF PARTICULATE MATTER IN AIR, 1962-1963

[Concentrations in pc/m^3]

Year	Average/sample	Maximum	Minimum
1962	4.47	31.05	0.37
1963	4.16	38.22	0.22

Precipitation Monitoring

Collection is made in a 0.4 square meter rain collector which delivers 1 liter of water for each 0.1 inch of precipitation. Even during relatively dry periods it has been found that this arrangement collected activity. By washing down the sides of the collector with 1 liter of distilled water, a suitable sample is obtained. These "wash" samples, as well as any precipitation, are reduced in volume, dry-plated on 1-inch stainless steel planchets, and counted in an automatic beta counting system, installed in late 1963. This system has a gas flow proportional counter, which provides increased efficiencies and lower background. (Counting was previously done in an end-window Geiger-Mueller counter with a window thickness of 1.9 mg/cm^2.

The present results are comparable with past results in that the same standard is used for determining geometry and efficiency. The counting efficiency is determined by comparison with a radium D + E standard which emits 1.17 Mev beta particles. Results are tabulated in table 7. Average "per day" values for the rain gauge collection are the total activity collected during the month divided by the number of days.

Table 7.—BETA ACTIVITY IN PRECIPITATION, 1962–1963

Year	Precipitation (mm.)	Deposition in pc/m^2 average/day
1962	303.19	1318
1963	452.88	1739

Previous coverage in *RHD*

Period	Issue
1960–1961	*October 1962*

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REPORTED NUCLEAR DETONATIONS, SEPTEMBER 1964

During September 1964 the AEC announced one underground nuclear test of low yield conducted on the fourth at the Nevada Test Site. (RHD reference number 166. Low yield is defined as equivalent to less than 20 kilotons of TNT.)

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RADIOLOGICAL HEALTH DATA

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service • Division of Radiological Health

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Section I—Air and Fallout

FISSION PRODUCT BETA ACTIVITY IN AIRBORNE PARTICULATES AND PRECIPITATION

Continuous surveillance of gross beta activity in air and precipitation provides one of the earliest and most sensitive indications of changes in environmental fission product activity. Although this surveillance does not provide enough information to assess human radiation exposure from fallout, it is widely used as the basis for alerting systems for determining when to intensify monitoring in other phases of the environment.

Surveillance data from a number of national programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. Data provided by programs of the Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization are presented individually in tabular form and are also compared in beta concentration isograms.

1. Radiation Surveillance Network
July 1964

Division of Radiological Health,
Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Surveillance Network (RSN) of the PHS Division of Radiological Health which gathers samples from 70 stations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The alerting function of the network is provided by field estimates of the gross beta activity of airborne particulates on the filters. These determinations are performed about 5 hours after the end of the sampling period to allow for decay of naturally-occurring radon daughters. The network station operators regularly submit their field estimates to the Radiation Surveillance Center, Division of Radiological Health, Washington, D. C. These field estimates are reported elsewhere on a monthly basis (*1*). When unusually high air levels are reported, appropriate Federal and State officials are promptly notified.

Air

Airborne particulates are collected continuously on carbon-loaded cellulose dust filters 4 inches in diameter. A volume of about 1800 cubic meters of air is drawn through each filter during the 24-hour sampling period by a high volume centrifugal blower.

The filters are forwarded to the Radiation Surveillance Network laboratory in Rockville, Maryland, where the gross beta activity is measured using a thin-window, gas-flow proportional counter, calibrated with a Sr^{90}-Y^{90} standard. Each filter is counted at least 3 days

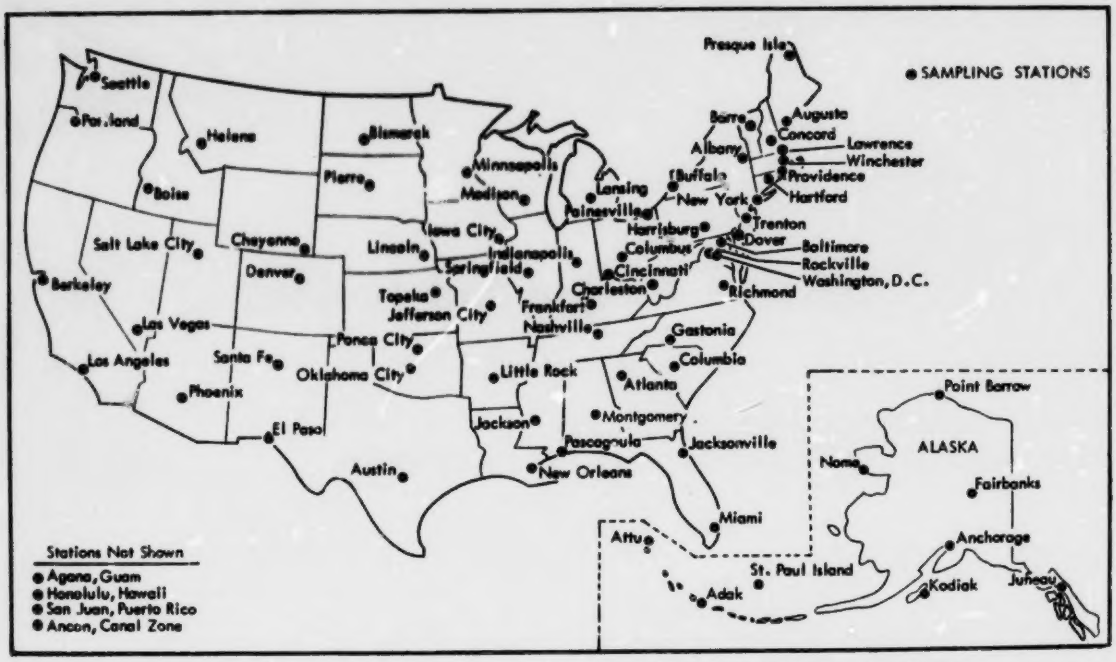
SAMPLING STATIONS
Seattle
Portland
Helena
Boise
Bismarck
Pierre
Minneapolis
Madison
Salt Lake City
Cheyenne
Lincoln
Iowa City
Indianapolis
Springfield
Denver
Berkeley
Topeka
Jefferson City
Frankfort
Las Vegas
Ponca City
Nashville
Los Angeles
Santa Fe
Oklahoma City
Little Rock
Phoenix
El Paso
Jackson
Montgomery
Atlanta
Austin
Pascagoula
New Orleans
Jacksonville
Miami
Lansing
Painesville
Buffalo
New York
Harrisburg
Columbus
Cincinnati
Charleston
Richmond
Gastonia
Columbia
Presque Isle
Augusta
Barre
Concord
Albany
Lawrence
Winchester
Providence
Hartford
Trenton
Dover
Baltimore
Rockville
Washington, D.C.
Point Barrow
ALASKA
Nome
Fairbanks
Anchorage
Juneau
Kodiak
Attu
St. Paul Island
Adak
Stations Not Shown
Agana, Guam
Honolulu, Hawaii
San Juan, Puerto Rico
Ancon, Canal Zone

FIGURE 1.—RADIATION SURVEILLANCE NETWORK SAMPLING STATIONS

after the end of the sampling period and again 7 days later. The initial 3-day aging of the sample eliminates interference from naturally-occurring radon and thoron daughters. By using the two counts and the Way-Wigner formula (*2*), the age of fission products is estimated, and the activity extrapolated to the time of collection.[1] The daily concentrations and estimated ages of selected samples are reported by the PHS in a monthly RSN report (*1*).

The twenty highest daily air measurements in July (table 1) ranged from 2.93 to 4.54 pc/m³. In June the twenty highest samples ranged from 4.85 to 6.62 pc/m³. Time profiles of gross beta activity in air for eight RSN stations are shown in figure 2. The July 1964 average gross beta concentration in air for each station is given in table 2. The network average for July (0.86 pc/m³) decreased from the June average (1.58 pc/m³).

Precipitation

Continuous sampling for total precipitation is conducted at most stations on a daily basis, using funnels with collection areas of 0.4 square meter. A 500-ml aliquot of the collected precipitation is evaporated to dryness, and the residue is forwarded to the laboratory for

TABLE 1.—GROSS BETA ACTIVITY OF THE TWENTY INDIVIDUAL RSN AIR FILTERS HAVING HIGHEST ACTIVITIES DURING JULY 1964

Station		Date July	Concentration (pc/m³)
Colo:	Denver	13	3.05
D.C:	Washington	2	3.08
Maine:	Augusta	1	2.93
Mich:	Lansing	5	3.01
		6	3.17
Nev:	Las Vegas	7	3.09
Ohio:	Painesville	1	3.09
		6	3.18
Pa:	Harrisburg	1	3.90
		2	3.81
		3	4.54
		6	3.94
		8	3.86
		11	3.00
		12	3.93
		15	3.16
		17	3.69
		18	4.49
Vt:	Barre	3	3.17
Utah:	Salt Lake City	7	3.63

---

[1] If a sample contains a mixture of fresh and old fission products, the age estimated by the Way-Wigner formula is some intermediate value and cannot be used for estimating date of formation.

TABLE 2.—GROSS BETA ACTIVITY IN SURFACE AIR AND PRECIPITATION, JULY 1964

Station location		Air surveillance					Precipitation measurements	
		Number of samples	Gross beta activity (pc/m³)			Last profile in *RHD*	Average concentration (pc/liter)	Total deposition (nc/m²)
			Maximum	Minimum	Average [a]			
Ala:	Montgomery	22	1.67	0.14	0.64	Aug 64	250	36.6
Alaska:	Adak	23	0.63	<0.10	0.19	Nov 64	[b]—	—
	Anchorage	31	1.05	<0.10	0.26	Jul 64	380	10.7
	Attu	31	1.33	<0.10	0.27	Dec 63	—	—
	Fairbanks	28	1.84	<0.10	0.64	Aug 64	380	11.9
	Juneau	7	0.39	<0.10	0.23	Sep 64	200	4.2
	Kodiak	17	0.92	<0.10	0.21	Oct 64	—	—
	Nome [c]							
	Point Barrow [c]							
	St. Paul Island	29	1.89	<0.10	0.40	Mar 64	—	—
Ariz:	Phoenix	28	1.73	0.28	0.55	Sep 64	—	—
Ark:	Little Rock	29	1.41	0.37	0.87	Sep 64	240	12.5
Calif:	Berkeley	23	0.74	<0.10	0.35	Oct 64	—	—
	Los Angeles	23	1.31	0.28	0.58	Feb 64	—	—
Canal Zone:	Ancon	11	0.21	<0.10	0.11	Nov 64	—	—
Colo:	Denver	28	3.05	0.37	0.85	Oct 64	200	4.0
Conn:	Hartford	31	2.07	0.18	0.82	Oct 64	270	19.7
Del:	Dover	21	2.50	0.20	0.90	Aug 64	—	—
D. C:	Washington	30	3.08	0.17	1.22	Aug 64	450	22.5
Fla:	Jacksonville	30	1.85	0.18	0.79	Sep 64	210	48.4
	Miami	30	1.38	0.32	0.79	Oct 64	240	43.4
Ga:	Atlanta	2	1.67	1.17	1.42	Jul 64	230	29.2
Guam:	Agana	29	0.43	<0.10	0.19	Apr 64	—	—
Hawaii:	Honolulu	31	1.22	<0.10	0.47	Feb 64	300	15.0
Idaho:	Boise	25	2.86	0.55	1.58	Dec 63	—	—
Ill:	Springfield	24	1.86	0.54	1.11	Mar 64	—	—
Ind:	Indianapolis	30	2.44	0.66	1.22	Jul 64	440	57.9
Iowa:	Iowa City	30	1.98	0.38	0.99	Nov 64	340	3.9
Kans:	Topeka	22	1.07	0.30	0.67	Jul 64	200	2.9
Ky:	Frankfort	30	2.15	0.62	1.20	Feb 64	400	16.9
La:	New Orleans	31	1.44	<0.10	0.51	Mar 64	200	26.4
Maine:	Augusta	31	2.93	0.30	0.97	Mar 64	380	52.3
	Presque Isle	28	2.90	0.26	0.96	Nov 64	450	31.9
Md:	Baltimore	22	2.13	0.12	0.94	Oct 64	420	17.8
	Rockville	20	1.56	0.25	0.82	Mar 64	—	—
Mass:	Lawrence	30	2.36	0.13	0.95	Aug 64	530	35.1
	Winchester	27	1.59	0.14	0.78	Apr 64	760	44.7
Mich:	Lansing	31	3.17	0.59	1.70	Feb 64	420	25.9
Minn:	Minneapolis	30	1.41	0.37	0.74	Mar 64	460	25.5
Miss:	Jackson	31	1.88	0.34	0.87	Apr 64	210	28.0
	Pascagoula [c]							
Mo:	Jefferson City	31	1.25	0.40	0.72	Jul 64	210	21.5
Mont:	Helena	30	2.15	0.23	1.21	Nov 64	1,000	24.0
Nebr:	Lincoln [c]							
Nev:	Las Vegas	26	3.09	0.24	0.87	Aug 64	—	—
N. H:	Concord	21	2.31	0.17	1.06	Feb 64	—	—
N. J:	Trenton	30	1.78	0.16	0.88	Apr 64	210	9.1
N. Mex:	Santa Fe	28	1.30	0.13	0.43	Nov 64	220	2.7
N. Y:	Albany	21	1.97	0.43	0.98	Jul 64		
	Buffalo	9	2.20	0.88	1.57	Nov 64	—	—
	New York	29	2.07	0.72	0.91	Dec 63	—	—
N. C:	Gastonia	31	2.31	0.17	0.84	Nov 64	200	43.4
N. Dak:	Bismarck	28	2.63	0.77	1.34	Feb 64	380	33.3
Ohio:	Cincinnati	21	1.72	0.75	1.12	Aug 64	—	—
	Columbus	31	2.90	0.81	1.59	Apr 64	730	54.9
	Painesville	29	2.18	0.89	1.74	Oct 64	410	35.7
Okla:	Oklahoma City	30	1.48	0.24	0.66	Apr 64	—	—
	Ponca City	31	0.96	0.10	0.43	Oct 64	330	6.2
Ore:	Portland	31	1.72	0.28	0.89	Oct 63	290	5.4
Pa:	Harrisburg	31	4.54	0.38	2.15	Jul 64	200	4.5
P. R:	San Juan	27	1.16	<0.10	0.65	Mar 64	230	7.5
R. I:	Providence	24	2.69	0.11	1.03	Jan 64	290	22.5
S. C:	Columbia	27	2.05	0.11	0.70	Dec 63	220	60.3
S. Dak:	Pierre	31	2.17	0.43	0.96	Sep 64	290	1.76
Tenn:	Nashville	31	2.69	0.32	1.06	Jan 64	450	37.5
Tex:	Austin	30	1.29	0.15	0.52	Aug 64	410	5.2
	El Paso	31	1.97	0.17	0.58	Jan 64	600	2.0
Utah:	Salt Lake City	31	3.63	0.26	1.10	Aug 63	760	0.9
Vt:	Barre	29	3.17	0.30	1.41	Sep 64	450	2.0
Va:	Richmond	31	2.10	<0.10	0.74	Sep 64	210	34.8
Wash:	Seattle	31	0.63	<0.10	0.25	Jul 64	480	9.1
W. Va:	Charleston	30	2.65	0.15	1.13	Dec 63	580	37.8
Wis:	Madison	30	2.00	0.48	1.32	Sep 54	290	26.6
Wyo:	Cheyenne	31	2.37	0.35	0.81	Aug 64	1,600	42.8
Network summary		1,878	4.54	<0.10	0.86		325	23.9

[a] The monthly average is calculated by weighting the individual samples with sampling period length. Values of <0.10 are assumed to be 0.10 for averaging purposes. If the <0.10 values represent more than 10 percent of the average, a less-than sign is placed before the average.
[b] Dash indicates no precipitation sample collected.
[c] Blank indicates no report received.

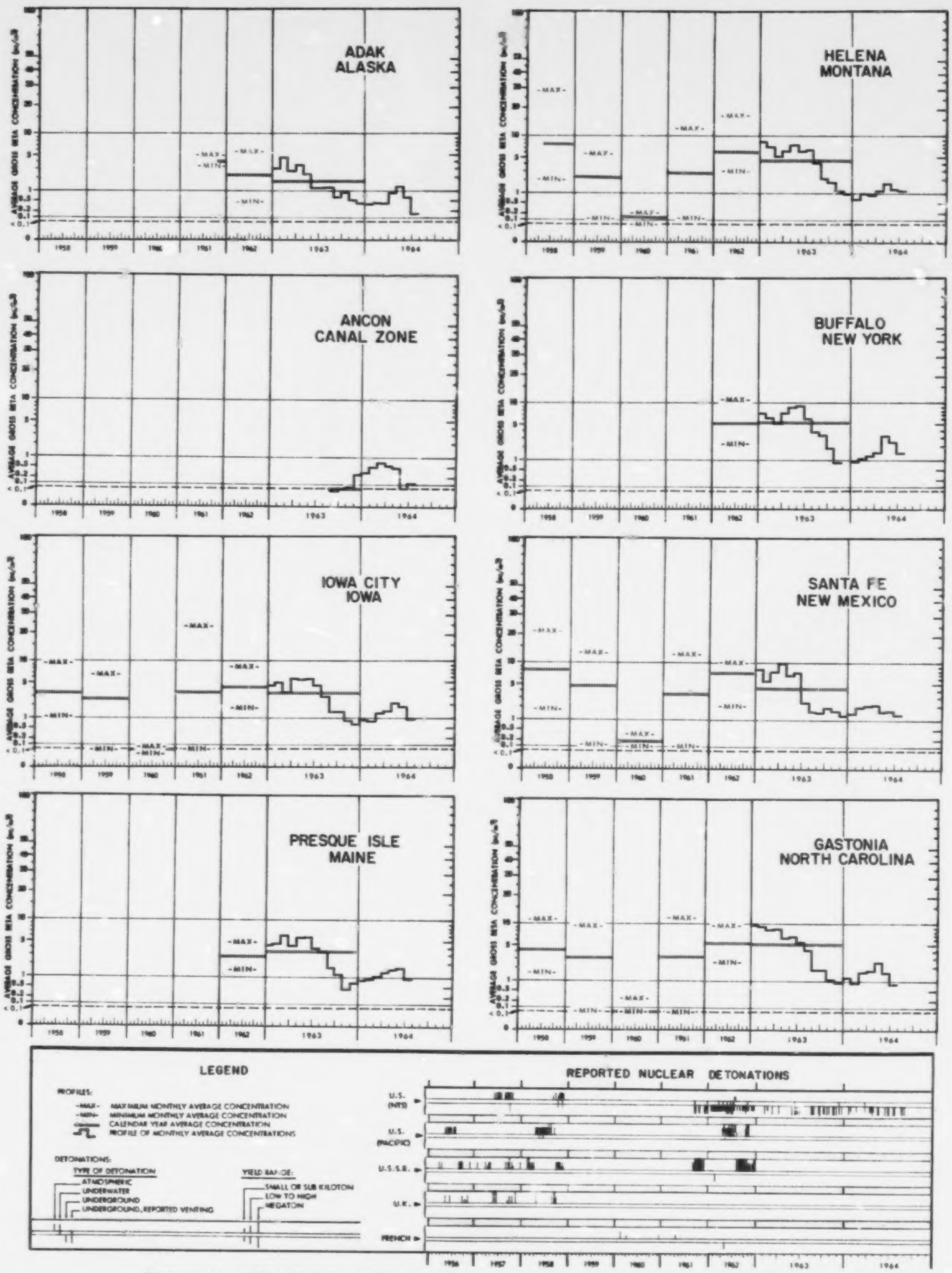

FIGURE 2.—MONTHLY AND YEARLY PROFILES OF BETA ACTIVITY IN AIR—RADIATION SURVEILLANCE NETWORK, 1958–JULY 1964

analysis. If the collected sample is between 200 and 500 ml, the entire sample is evaporated. When a sample is smaller than 200 ml (equivalent to 0.5 mm or 0.02 inches of rainfall), the volume of precipitation is reported, but no analysis is made.

In the laboratory the gross beta activity in precipitation is determined by counting the evaporated sample by the same method used for analyzing the air filters, including the extrapolation to time of collection. Deposition for the sample is determined by:

$$D = \frac{CP}{1000}$$

where D is the deposition in nc/m^2, C is the concentration in pc/liter, and P is the depth of precipitation in mm. The individual values of deposition and depth of precipitation are totaled for the month, and the average concentration for the month, $\bar{C}$, is determined by:

$$\bar{C} = \frac{\Sigma D}{\Sigma P} \times 1000$$

The July 1964 average concentrations and total depositions are given in table 2.

2. Canadian Air Monitoring Program[2]
July 1964

Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (see figure 3), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of the National Health and Welfare (*3–7*).

Air

Each air sample involves the collection of particulates from about 650 cubic meters of air drawn through a high-efficiency 4-inch-diameter filter during a 24-hour period. These filters are sent daily to the Radiation Protection Division Laboratory in Ottawa. At the laboratory, a 2-inch-diameter disk is cut from each filter and counted with a thin-end-window, gas-flow, Geiger-Mueller counter system, calibrated with a Sr^{90}–Y^{90} standard. Four successive measurements are made on each filter to permit correction for natural activities and for the decay of short-lived fission products. The results are extrapolated to the end of the sampling period. Canadian air data for July 1964 are given in table 3 and presented in conjunction with U. S. and Mexican data by an isogram map (figure 5).

Precipitation

The amount of radioactive fallout deposited on the ground is determined from measurements on material collected in special polyethylene-lined rainfall pots. The collection period for each sample is one month. After transfer of the water to the sample container, the polyethylene liner is removed, packed with the sample, and sent to the laboratory.

Strontium and cesium carriers are added to all samples on arrival at the laboratory. Other carriers are also added to selected samples according to the specific radionuclides to be determined. The samples are then filtered and the filtrate evaporated to near dryness. The filter paper containing insoluble matter is ignited together with the polyethylene liner at 450° C. The ash is combined with the soluble fraction, transferred to a glass planchet, evaporated under an infra-red lamp and then counted with a thin-end-window Geiger-Mueller counter calibrated with a Sr^{90}–Y^{90} source. Gross beta activities for July 1964 samples are given in table 3. Radionuclide analyses are reported quarterly in *RHD*.

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[2] Data from *Radiation Protection Programs, Vol. 2, No. 8:* 11-24, Radiation Protection Division, Canadian Department of National Health and Welfare, Ottawa, Canada.

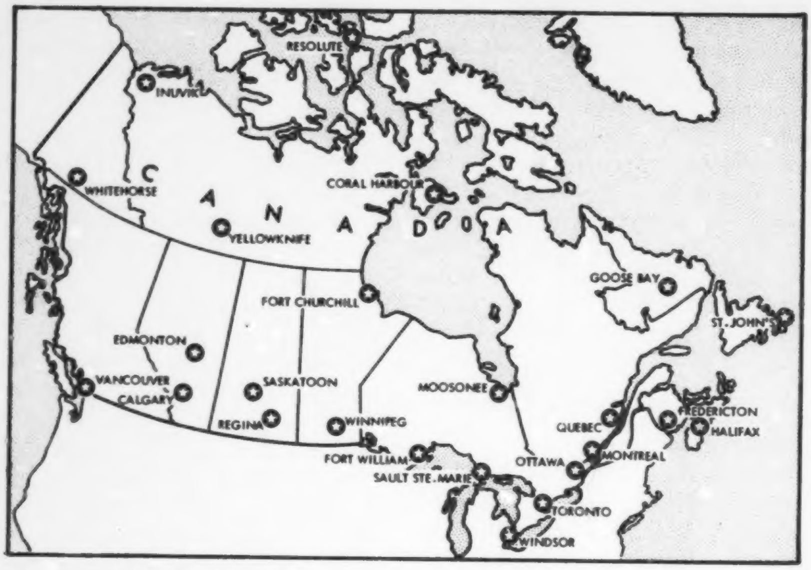

RESOLUTE
INUVIK
C
A
N
A
D
A
WHITEHORSE
YELLOWKNIFE
CORAL HARBOUR
GOOSE BAY
FORT CHURCHILL
ST. JOHN'S
EDMONTON
VANCOUVER
CALGARY
SASKATOON
REGINA
WINNIPEG
MOOSONEE
QUEBEC
FREDERICTON
HALIFAX
MONTREAL
FORT WILLIAM
SAULT STE. MARIE
OTTAWA
TORONTO
WINDSOR

FIGURE 3.—CANADIAN AIR AND PRECIPITATION SAMPLING STATIONS

TABLE 3.—GROSS BETA ACTIVITY IN SURFACE AIR AND PRECIPITATION, CANADA, JULY 1964

Station	Air surveillance				Precipitation data	
	Number of samples	Gross beta activity (pc/m³)			Average concentration (pc/liter)	Total deposition (nc/m²)
		Maximum	Minimum	Average		
Calgary	31	2.4	0.8	1.4	480	34.6
Coral Harbour	30	2.3	0.1	0.9	1,201	13.7
Edmonton	31	1.8	0.3	1.0	525	39.4
Ft. Churchill	31	1.9	0.1	0.9	894	40.8
Ft. William	29	1.7	0.4	1.0	1,067	19.8
Fredericton	31	2.2	0.1	0.8	466	26.5
Goose Bay	31	1.6	0.1	0.8	470	60.1
Halifax	28	2.2	0.1	0.5	334	48.3
Inuvik	31	2.5	0.1	1.0	752	46.6
Montreal	30	2.6	0.2	1.2	431	49.9
Moosonee	30	2.1	0.1	1.0	472	20.6
Ottawa	29	2.3	0.5	1.1	647	59.3
Quebec	29	2.2	0.1	1.0	518	41.1
Regina	31	2.8	0.8	1.4	886	81.8
Resolute	30	1.3	0.1	0.3	102	26.4
St. John's, Nfld	29	2.1	0.1	0.7	253	25.7
Saskatoon	30	2.5	0.4	1.3	1,188	26.5
Sault Ste. Marie	28	2.3	0.3	1.1	277	29.0
Toronto	31	1.8	0.4	1.1	431	49.0
Vancouver	31	0.9	0.1	0.4	604	48.1
Whitehorse	30	1.5	0.1	0.5	488	17.6
Windsor	30	2.5	0.5	1.2	699	38.5
Winnipeg	31	1.9	0.5	1.2	1,346	30.7
Yellowknife	31	2.2	0.3	1.2	1,647	6.7
Network summary		2.1	0.1	1.0	674	36.7

3. Mexican Air Monitoring Program
July 1964

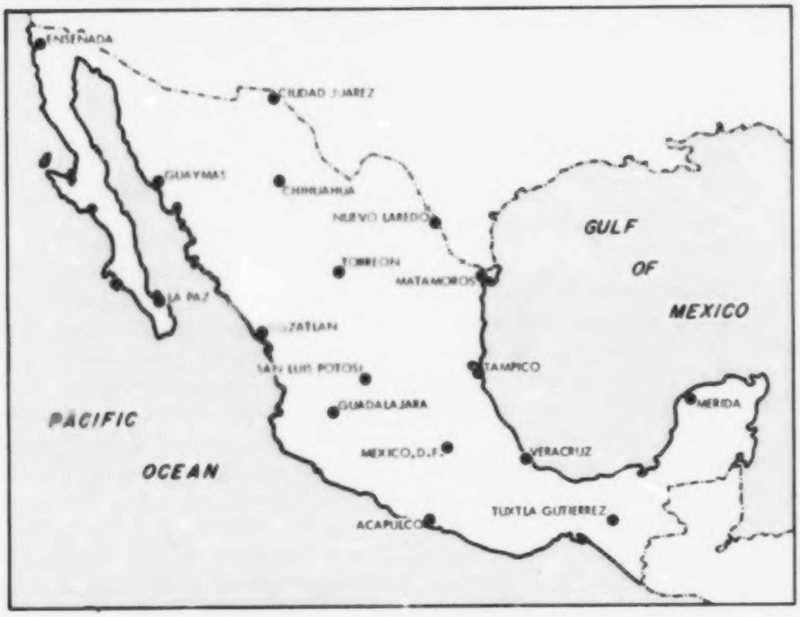
National Commission of Nuclear Energy

The Radiation Surveillance Network of Mexico was established by the *Comisión Nacional de Energía Nuclear* (CNEN), Mexico City. From 1952 to 1961 the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN (*8–12*).

In 1961 the CNEN appointed its Division of Radiological Protection to establish a new Radiation Surveillance network. This network consists of 17 stations (see figure 4), twelve of which are located at airports and operated by airline personnel. The remaining five stations are located at Mexico City, Mérida, Veracruz, San Luis Potosí and Ensenada. Staff members of the DRP operate the station at Mexico City while the other four stations are manned by members of the Centro de Previsión del Golfo de México, the Chemistry Department of the University of Mérida, the Institute de Zonas Dersérticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air for 24 hours a day, 3 or 4 days a week at the rate of approximately 1,200 cubic meters per day, through a high-efficiency, 6 x 8-inch glass fiber filter, using high volume samplers. After each 24 hour sampling period, the filter is removed and forwarded via air mail to the "Laboratorio de Estudios sobre Contaminación Radiactiva", CNEN, in Mexico City for assay of gross beta activity. A minimum of 3 or 4 days after collection is allowed for decay of radon and thoron daughter natural radioactivity. Data are not extrapolated to time of collection.


ENSENADA
CIUDAD JUAREZ
GUAYMAS
CHIHUAHUA
NUEVO LAREDO
TORREON
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ZATLAN
SAN LUIS POTOSI
GUADALAJARA
TAMPICO
MERIDA
MEXICO, D.F.
VERACRUZ
ACAPULCO
TUXTLA GUTIERREZ
GULF OF MEXICO
PACIFIC OCEAN

FIGURE 4.—FALLOUT NETWORK SAMPLING STATIONS IN MEXICO

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Results

The maximum, minimum and average fission product beta concentrations in surface air during July 1964 are presented in table 4. The data are also represented in the beta activity isogram map of North America, figure 5.

TABLE 4.—GROSS BETA ACTIVITY OF AIRBORNE PARTICULATES, MEXICO, JULY 1964

[Concentrations in pc/m³]

Station	Number of Samples	Maximum	Minimum	Average
Acapulco	11	0.3	0.1	0.2
Ciudad Juárez	25	1.0	0.1	0.4
Chihuahua	15	1.5	0.1	0.6
Ensenada	11	1.0	0.2	0.6
Guadalajara	12	0.4	0.1	0.3
Guaymas	19	0.9	0.3	0.5
La Paz	18	1.0	0.1	0.5
Matamoros	23	1.2	0.1	0.4
Mazatlán	6	0.7	0.1	0.2
Mérida	9	1.0	0.1	0.3
México, D.F.	14	0.9	0.1	0.3
Nuevo Laredo	13	1.5	0.2	0.6
San Luis Potosí	11	0.4	0.1	0.2
Tampico	31	2.0	0.1	0.4
Torreón	24	0.9	0.1	0.5
Tuxtla Gutiérrez [a]				
Veracruz	21	1.3	0.1	0.4

[a] Temporarily shut down.

4. Pan American Air Sampling Program July 1964

Pan American Health Organization and Public Health Service

Gross beta activity in air is monitored by four countries in the Americas under the auspices of a collaborative program developed by the Pan American Health Organization and the Public Health Service (PHS) for assisting countries of the Americas in developing radiological health programs. The sampling equipment and analytical services are provided by the Division of Radiological Health, PHS, and are identical with those employed for the Radiation Surveillance Network.

The four air sampling stations included in the program are operated by the technical staff of the Ministry of Health in each country. The station in Kingston, Jamaica, is operated by the Public General Hospital; in Caracas, Venezuela, by the Venezuelan Institute for Scientific Investigations; in Lima, Peru, by the Institute of Occupational Health; and in Santiago, Chile, by the Occupational Health Service. The Kingston station began operation in March 1964, and the other three were started near the end of 1962.

The July 1964 air monitoring results from the four participating countries are given in table 5. The Caracas and Jamaica stations, included in figure 5 with the July averages adjusted by the RSN intercalibration factor,[3] were used in positioning the beta concentration isograms.

TABLE 5.—GROSS BETA ACTIVITY IN AIR, JULY 1964

[Concentrations in pc/m³]

Sampling stations	No. of samples	Maximum	Minimum	Average [a]
Kingston, Jamaica	18	0.92	0.22	0.51
Caracas, Venezuela	22	0.82	<0.10	0.23
Lima, Peru	22	0.17	<0.10	0.10
Santiago, Chile	13	0.73	<0.10	0.18

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes. If the <0.10 values represent more than 10 percent of the average, a less-than sign is placed in front of the average.

5. Gross Beta Activity In Air, North America July 1964

Beginning with January 1963 data, monthly average concentrations of airborne gross beta activity in Canada and the United States have been presented in combined form as isogram maps of most of North America. The data from the Radiation Surveillance Network and the Canadian Air Network were adjusted to each other by means of an intercalibration factor derived by Lockhart and Patterson (*13*).

With the formation of the Mexican Air monitoring program, new intercalibration ratios were determined, this time including the Canadian Network, Radiation Surveillance Network, National Air Sampling Network, the HASL 80th Meridian Network, and the Mexican Network (*14*). The new intercalibration factors reflect some changes in standardization in both the RSN and the Canadian Air Network, effective September 1963.

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[3] The RSN factor is 1.28.

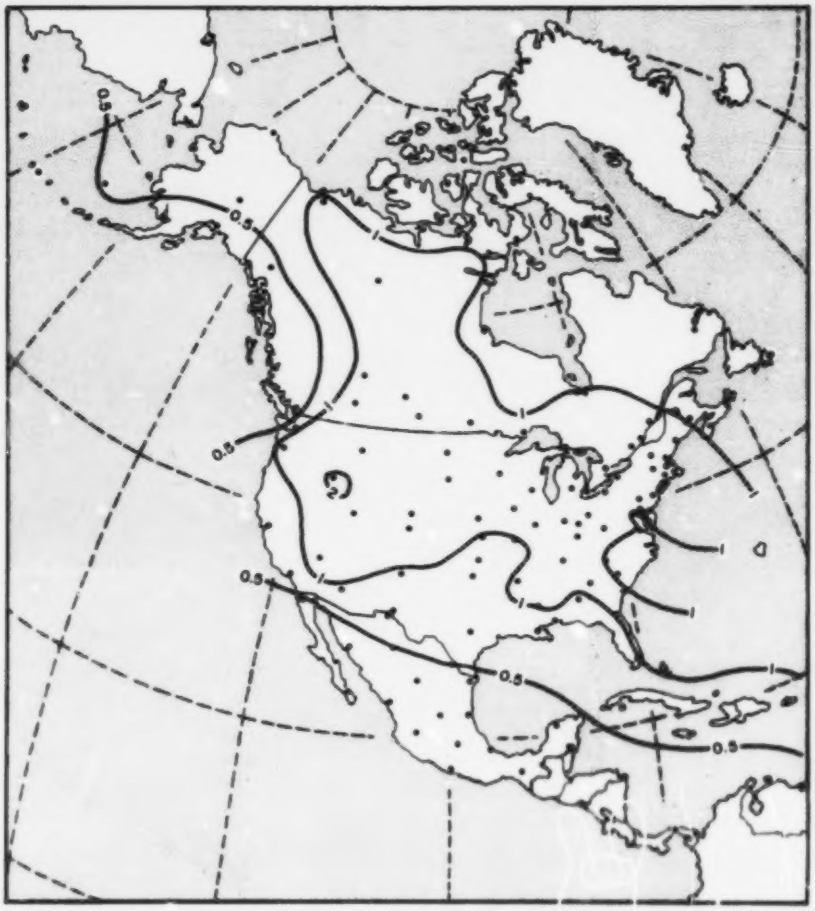

FIGURE 5.—ISOGRAM OF AVERAGE GROSS BETA CONCENTRATIONS IN AIR, NORTH AMERICA, JULY 1964

Figure 5 shows the July 1964 activity in air throughout North America based on the data from the Canadian Air Monitoring Program, the Radiation Surveillance Network and Mexican Air Monitoring program. An intercalibration factor of 1.28 was applied to the RSN data and the Mexican data were multiplied by 0.81 in order to adjust them to Canadian data.

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EVALUATION OF RADIATION SURVEILLANCE NETWORK EXTERNAL GAMMA RADIATION DATA, 1959–1963

Warren W. Church[1]

The Radiation Surveillance Network (RSN) was established in 1956 to provide information on gross beta activities in surface air and in precipitation throughout the United States. Daily measurements of external gamma activity were made in addition to the collection of air and precipitation samples at each of the network's seventy-four stations.

The methodology used by the RSN for measuring external gamma activity (*1*) is briefly described as follows: The probe of a Geiger-Mueller survey meter (Thyac model 389 or model 489) is held three feet above the roof or ground for 60 seconds. During this period the operator estimates the average meter reading. (Prior to any measurements, the probe is held up to a small check source to insure that the meter is operating properly).

The Public Health Service reported monthly averages of external gamma activities at each station in the *Tabulation of Findings, Public Health Service, Radiation Surveillance Network*, (*2*) for the period May 1956 through September 1962, and in *Radiological Health Data* (*3*) for the period January 1960 through September 1962.

Significance of External Gamma Measurements

After the reporting of external gamma measurements was discontinued in September 1962, a study was made to determine whether departures noted in individual stations during the period, 1959–1963, could be associated with other fallout data and whether the routine reporting of monthly averages was warranted.

Table 1 was developed to show the maximum, minimum and median monthly average external gamma measurements for each station from November 1959 through September 1962. With respect to the variability of these averages, nine of the stations consistently reported only one value. Only one or two readings deviated from the median at several other stations.

As a further evaluation of external gamma data, two statistical techniques were employed. First, a control chart was prepared to determine possible trends in external gamma averages (figure 1). Secondly, a correlation study was made to determine if changes in individual external gamma measurements could be related to fallout activity deposited by precipitation.

In the first study, composite monthly external gamma averages were plotted against time. (The geographically representative stations selected for this chart are indicated by

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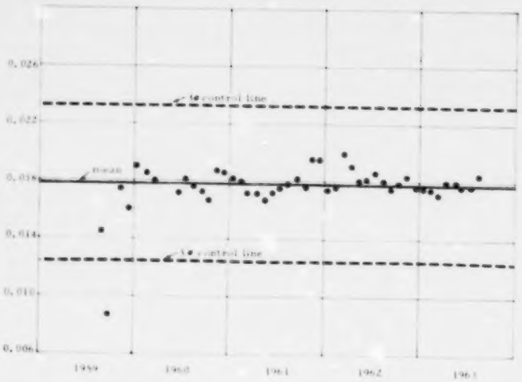

FIGURE 1.—CONTROL CHART—MONTHLY EXTERNAL GAMMA AVERAGES FROM 21 REPRESENTATIVE RSN STATIONS

footnote reference a in table 1). A line representing the mean of the composite averages and two dashed lines indicating the three-sigma deviations from this mean are used as control lines on the graph. Since all points on the graph are grouped around the mean and are well within the three-sigma control lines, it can be concluded that the composite data did not indicate any significant changes or trends in the external gamma averages during the period from November 1959 through July 1963.

Daily variations in external gamma activity at 21 representative RSN stations were studied next to determine whether they could be related to reported increases in fallout deposition. Since other studies (*4–6*) have shown that most world-wide fallout is deposited on the ground by means of precipitation and that very little reaches the earth as "dry fallout," an attempt was made to relate reports of gross beta activities from individual rainfalls and snowfalls to external gamma activities, measured directly during or after the period of precipitation. Data collected during the period from September 1961 through August 1962, when the RSN recorded relatively high precipitation activities were analyzed. Correlation coefficients[2] were computed by comparing gross beta activities in precipitation and external gamma activities (*7*). The results are presented in table 2.

The significance of each correlation coefficient was tested and it was found that correlations for only 5 of the 21 stations tested were statistically significant (i.e., different from zero) at the 95 percent confidence level (*7*). For two of these stations the correlation was negative (negative correlation indicates that, as activities in precipitation increase, the corresponding external gamma activities tend to decline). For practical purposes no clear relationship could be established between RSN external gamma measurements and fallout deposited by precipitation.

TABLE 1.—MINIMUM, MAXIMUM AND MEDIAN MONTHLY AVERAGE RSN EXTERNAL GAMMA MEASUREMENTS FOR EACH STATION REPORTED BY THE PHS, NOVEMBER 1959 THROUGH SEPTEMBER 1962

Station location	Minimum (mr/hr)	Maximum (mr/hr)	Median (mr/hr)
Anchorage, Alaska	0.01	0.01	0.01
Fairbanks, Alaska	0.01	0.01	0.01
Juneau, Alaska [a]	0.01	0.02	0.01
Phoenix, Ariz	0.01	[b] 0.09	0.01
Little Rock, Ark. [a]	0.01	0.02	0.02
Berkeley, Calif. [a]	0.01	0.02	0.01
Los Angeles, Calif	0.01	0.02	0.01
Denver, Colo	0.02	0.02	0.02
Hartford, Conn	0.01	0.02	0.01
District of Columbia [a]	0.02	0.04	0.02
Jacksonville, Fla. [a]	0.01	0.03	0.01
Atlanta, Ga. [a]	0.02	0.03	0.02
Honolulu, Hawaii [b]	0.01	0.05	0.02
Boise, Idaho	0.01	0.02	0.02
Springfield, Ill	0.01	0.03	0.01
Indianapolis, Ind. [a]	0.01	0.02	0.01
Iowa City, Iowa [a]	0.01	0.03	0.01
Topeka, Kans	0.02	0.03	0.02
New Orleans, La. [a]	0.01	0.02	0.01
[illegible]	0.01	0.02	0.02
Lawrence, Mass. [a]	0.01	0.02	0.02
Lansing, Mich	0.02	0.02	0.02
Minneapolis, Minn. [a]	0.01	0.02	0.01
Jefferson City, Mo	0.01	0.01	0.01
Helena, Mont. [a]	0.01	[b] 0.07	0.03
Trenton, N. J	0.02	0.02	0.02
Santa Fe, N. Mex. [a]	0.03	0.05	0.04
Albany, N. Y	0.01	[b] 0.09	0.02
Gastonia, N. C	0.02	0.02	0.02
Oklahoma City, Okla. [a]	0.01	0.03	0.02
Ponca City, Okla	0.02	0.04	0.04
Portland, Ore. [a]	0.01	0.02	0.02
Harrisburg, Pa	0.01	0.02	0.01
Providence, R. I	0.01	0.02	0.02
Columbia, S. C	0.02	0.03	0.02
Pierre, S. Dak	0.02	0.02	0.02
Austin, Tex.[a]	0.01	0.02	0.01
El Paso, Tex	0.01	0.03	0.02
Salt Lake City, Utah	0.02	0.02	0.02
Richmond, Va.[a]	0.01	0.02	0.01
Seattle, Wash.[a]	0.01	0.02	0.02
Madison, Wis	0.01	0.02	0.02
Cheyenne, Wyo.[a]	0.01	0.02	0.02

[a] Stations used for averages in figure 1.
[b] High maximums due to faulty survey instruments.

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[2] $$r=\frac{n\Sigma x_i y_i-(\Sigma x_i)(\Sigma y_i)}{\sqrt{n\Sigma x_i^2-(\Sigma x_i)^2}\sqrt{n\Sigma y_i^2-(\Sigma y_i)^2}}$$

Where: r=Correlation coefficient
n=Number of precipitation periods
y=Precipitation activity $\frac{(\text{pc})}{(\text{m}^2)}$
x=External gamma activity $\frac{(\text{mr})}{(\text{hr})}$

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As a final step in this study, a review of RSN data for the summer of 1957 was made to determine if excursions of gross beta activities in air samples at individual stations were accompanied by corresponding increases in external gamma levels. The summer of 1957 was chosen because it was during this period that the RSN reported the highest levels of gross beta activity in air and precipitation samples. There were several instances during this period when external gamma levels were found to increase with increases in gross beta levels in air, as at Boise, Idaho, Pierre, South Dakota, and Salt Lake City, Utah. The levels at Salt Lake City are shown graphically in figure 2. After 1957 no clear relationship between gross beta and external gamma levels was discerned.

TABLE 2.—COMPARISON OF PRECIPITATION DEPOSITION AND CORRESPONDING EXTERNAL GAMMA MEASUREMENTS, SEPTEMBER 1961–AUGUST 1962

Station	Number of precipitation samples	Average deposition nc/m²	Average external gamma mr/hr	Correlation coefficient
Juneau, Alaska	119	30	0.014	[a] 0.24
Little Rock, Ark	47	26	0.010	undefined
Berkeley, Calif	27	21	0.014	0.16
Washington, D. C	61	13	0.024	0.01
Jacksonville, Fla	52	10	0.012	0.03
Atlanta, Ga	32	16	0.026	0.18
Honolulu, Hawaii	35	9	0.026	[a] 0.44
Indianapolis, Ind	73	20	0.010	0.08
Iowa City, Iowa	66	18	0.019	0.04
Topeka, Kans	51	34	0.022	0.03
New Orleans, La	73	18	0.015	0.03
Lawrence, Mass	55	17	0.019	[a] −0.35
Minneapolis, Minn	74	15	0.011	[a] 0.43
Helena, Mont	49	14	0.030	0.17
Santa Fe, N. Mex	24	9	0.038	[a] −0.45
Albany, N. Y	58	7	0.028	0.04
Oklahoma City, Okla	17	8	0.017	0.41
Portland, Ore	70	19	0.020	0.02
Richmond, Va	59	18	0.011	0.01
Seattle, Wash	74	13	0.015	−0.12
Cheyenne, Wyo	38	13	0.021	−0.06

[a] Correlations that are statistically significant. (2σ).

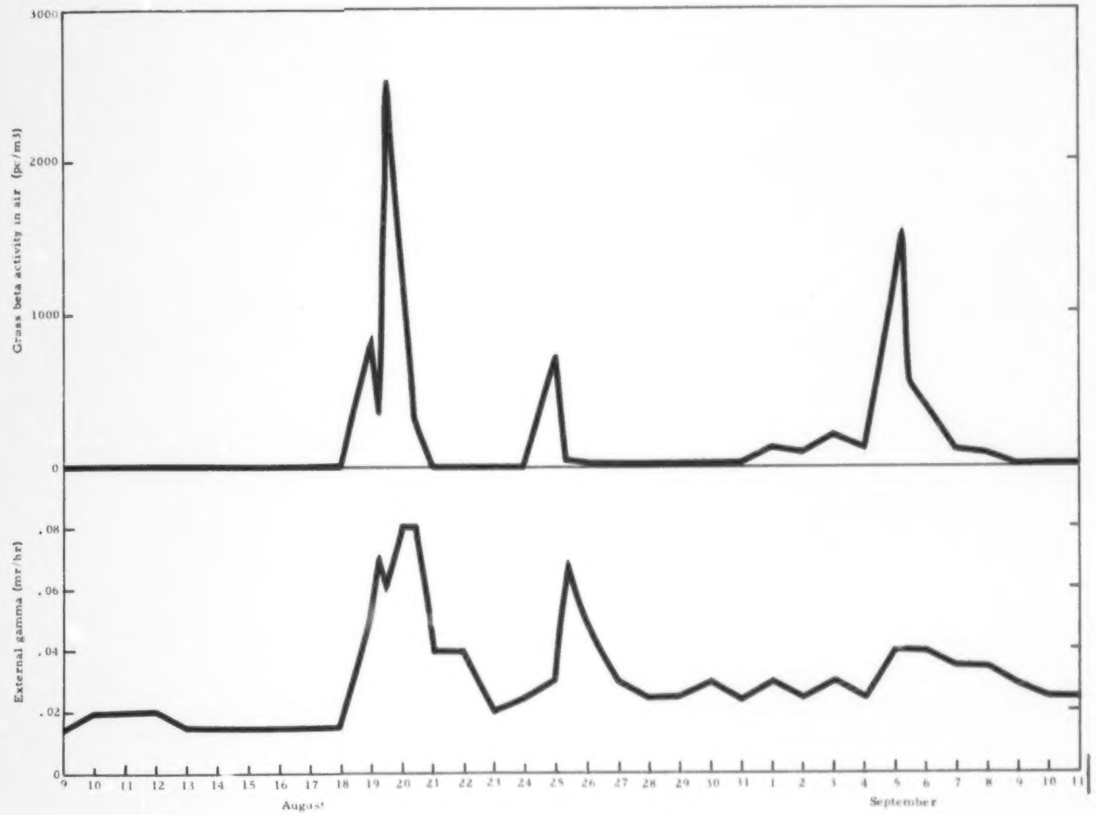

FIGURE 2.—GROSS BETA LEVELS IN AIR AND EXTERNAL GAMMA LEVELS AT SALT LAKE CITY, UTAH, DURING THE SUMMER OF 1957

Discussion

It can be deduced from the work of Knapp (*8*) and from a report by the U. S. Department of Defense (*9*) that external gamma increases approximately .001 mr/hr for every 30 nanocuries/m² of fallout deposited on the ground. Since few RSN stations have reported individual rainfall depositions in excess of 300 nc/m², only rarely would fallout deposition have been expected to have caused external gamma to increase by more than 0.01 mr/hr.

The RSN survey instruments are not sufficiently sensitive to measure small changes in external gamma activity. The normal range of external gamma measurements is from 0.01 to 0.04 mr/hr. These measurements are made at the extreme end of the lowest range of the survey meters. At such low readings, the manuals for the instruments claim an accuracy of ±10 percent of the full scale or ±0.02 mr/hr. Thus, a typical external gamma activity measurement of 0.02 mr/hr could be as much as 100 percent in error. This would tend to conceal small variations in monthly external gamma activity averages, and no definite correlation should be expected between external gamma measurements and precipitation deposition, as long as deposition levels remained below 300–600 nc/m².

Part of the lack of correlation between precipitation deposition and external gamma measurements may also have been due to the location of the external gamma measurements, since most were taken above hard surfaces such as rooftops. It is possible that much of the activity that was brought down by the rain was also washed off the surface by the same rain.

Summary

The RSN external gamma measurements are not effective indicators of fission product intrusions for the period 1959–1963. Instruments of greater sensitivity and different techniques of measurement would be needed to detect the small changes in external gamma activity associated with fallout deposited during this period.

Since the present method is sensitive to such external radiation as experienced in the summer of 1957, it would seem advisable that the RSN continue these gamma measurements. The RSN is the only nationwide network presently making such measurements and it is conceivable that fallout on the order of one μc/m² could cause external gamma levels to increase by amounts such as those experienced in the summer of 1957.

Acknowledgement

The author gratefully acknowledges the statistical assistance of the Biometrics Unit of the Research Branch, Division of Radiological Health.

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Section II—Milk and Food

MILK SURVEILLANCE

Although milk is only one of the many sources of dietary intake of radionuclides, it is the single food item most often used as an indicator of the population's intake of radionuclides from the environment. This is because fresh milk is consumed by a large segment of the United States population and contains most of the radionuclides occurring in the environment which have been identified as biologically important. In addition, milk is produced and consumed on a regular basis, is convenient to handle, is easily analyzed, and samples which are representative of milk consumption in any area can be readily obtained.

1. Pasteurized Milk Network
July 1964

Division of Radiological Health and
Division of Environmental Engineering and
Food Protection, Public Health Service

The Public Health Service pasteurized milk surveillance program had its origin in a raw milk monitoring network (*1*) established by the Service in 1957. One of the primary objectives of the raw milk network was the development of methods for milk collection and radiochemical analysis suitable for larger scale programs.

Experience derived from this earlier network led to the activation of a pasteurized milk sampling program with stations selected to provide nationwide surveillance of milk production and consumption areas. The present network, which consists of 63 stations, has at least one station in every State, the Canal Zone, and Puerto Rico.

Sampling Procedure

Through the cooperation of State and local milk sanitation authorities, samples are routinely collected at each station. The method specifies that each station's sample be composited of subsamples from each milk processing plant in proportion to the plant's average sales in the community served. At most stations the sample represents from 80 to 100 percent of the milk processed. Prior to September 15, 1961, the composite sample was taken from one day's sales per month and was as representative of the community's supply as could be achieved under practical conditions. Beginning with the resumption of nuclear weapons testing in the atmosphere in September 1961, and continuing through January 1963, samples were collected twice a week at nearly all stations and daily for short periods at selected stations. Since then the sampling frequency has been reduced to once a week.

Samples are preserved with formaldehyde and are sent to the PHS Southwestern (SWRHL), Southeastern (SERHL), or Northeastern Radiological Health Laboratories (NERHL) for analysis. Gamma analyses for iodine-131 are made within 3 to 6 days after sample collection, and any results exceeding 100 pc/liter are immediately telephoned to State health officials for possible public health action. Analytical results are normally available 6 to 7 weeks after monthly samples are received by the laboratories; publication in *RHD* follows 3 to 4 months after the monthly samples are composited for analyses.

Analytical Procedures

Iodine-131, cesium-137, and barium-140 concentrations are determined by gamma scintillation spectroscopy.[1] After the weekly samples are gamma scanned, samples from two consecutive weeks are composited and analyzed radiochemically for strontium-89 and strontium-90. There is an inherent statistical variation associated with all measurements of radionuclide concentrations. With the low radionuclide levels which are usually found in milk and other environmental samples, this variation on a percentage basis is relatively high. The variation depends upon such factors as the method of chemical analysis, the sample counting rate and counting time, interferences from other radionuclides and the background count. For milk samples, counting times of 50 minutes for gamma spectroscopy and 30 to 50 minutes for beta determinations are used. Table 1 shows the approximate total analytical error (including counting error) associated with radionuclide concentrations in milk. These errors were determined by comparing results of a large number of replicate analyses. Table 1 gives the 95% confidence limits between which the true concentrations of the selected radionuclides might be expected in the analyses. The minimum detectable concentration is defined as the measured concentration at which the two-standard-deviation analytical error is equal to the measurement. Accordingly, the minimum detectable concentrations in units of pc/liter are Sr^{89}, 5; Sr^{90}, 2; Cs^{137}, 10; Ba^{140}, 10; and I^{131}, 10. At these levels and below, the counting error comprises nearly all of the analytical error.

TABLE 1.—ANALYTICAL ERRORS ASSOCIATED WITH ESTIMATED CONCENTRATIONS FOR SELECTED RADIONUCLIDES IN MILK

Nuclide	Estimated concentration (pc/liter)	Error [a] (pc/liter)	Estimated concentration (pc/liter)	Error [a] (percent of concentration)
Iodine-131	0 to 100	±10	100 or greater	±10%
Barium-140	0 to 100	±10	100 or greater	±10%
Cesium-137	0 to 100	±10	100 or greater	±10%
Strontium-89	0 to 50	±5	50 or greater	±10%
Strontium-90	0 to 20	±2	20 or greater	±10%

[a] Two standard deviations (2σ).

Calcium analyses at SERHL are done by an ion exchange and permanganate titration method while at NERHL and SWRHL an ethylenediaminetetraacetic acid (EDTA) method is used. Stable potassium concentrations are estimated from the potassium-40 concentrations determined from the gamma spectrum.[2]

Data Presentation

Table 2 presents summaries of the analyses for July 28, 1964–July 25, 1964. Although not shown in table 2, the iodine-131 and barium-140 monthly average concentrations in milk were less than 10 pc/liter. Radionuclide values reported by a laboratory as being below the minimum detectable concentration have been averaged by using one-half the minimum detectable value. The averaging procedure was modified for iodine-131 and barium-140 in October 1963 when nondetectable concentrations of these radionuclides were considered zero. A similar procedure is used for the network average.

Figures 1 and 2 are isogram maps showing the estimated strontium-90 and cesium-137 concentrations in milk over the entire country. The value printed beside each station is the monthly average concentration for that station. The isograms were developed by arbitrary interpolation between values for the individual stations. Additional modifications to the isograms are made according to available information on milksheds.

In order to develop the distribution of the network's stations *versus* radionuclide concentrations in milk, table 3 has been prepared using monthly averages shown in table 2.

The average monthly strontium-90 concentrations in pasteurized milk from selected cities

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[1] Southeastern Radiological Health Laboratory employs a radiochemical procedure for barium-140 analysis.

[2] The conversion factor is 1.18×10^{-3} g K/pc K^{40}.

TABLE 2.—STABLE ELEMENT AND RADIONUCLIDE CONCENTRATIONS IN PASTEURIZED MILK, JULY 1964 [a] [b]

[Average radioactivity concentrations in pc/liter]

Sampling locations		Calcium (g/liter)		Potassium (g/liter)		Strontium-89		Strontium-90		Cesium-137		Last Sr^{90} graph in *RHD* (1964)
		Second quarter	Avg. for month	Second quarter	Avg. for month	Second quarter	Avg. for month	Second quarter	Avg. for month	Second quarter	Avg. for month	
Ala:	Montgomery	1.15	1.17	1.5	1.5	<5	<5	26	21	90	70	Oct
Alaska:	Palmer	1.22	1.15	1.4	1.5	5	<5	25	20	150	110	Nov
Ariz:	Phoenix	1.17	1.16	1.5	1.5	<5	<5	6	3	30	20	Sep
Ark:	Little Rock	1.15	1.16	1.5	1.5	<5	<5	58	40	160	90	Nov
Calif:	Sacramento	1.24	1.25	1.5	1.5	<5	<5	9	7	50	35	Aug
	San Francisco	1.22	1.19	1.4	1.5	<5	<5	12	8	55	40	Oct
Canal Zone:	Cristobal	1.09	1.11	1.5	1.6	<5	<5	6	4	55	50	Nov
Colo:	Denver	1.22	1.20	1.5	1.4	<5	<5	22	24	90	120	Aug
Conn:	Hartford	1.14	1.13	1.5	1.6	<5	<5	23	22	160	130	Aug
Del:	Wilmington	1.20	1.16	1.5	1.5	<5	<5	30	23	145	110	Sep
D. C:	Washington	1.12	1.11	1.6	1.5	<5	<5	23	22	100	80	Oct
Fla:	Tampa	1.13	1.18	1.5	1.6	<5	<5	15	17	260	260	Sep
Ga:	Atlanta	1.15	1.17	1.5	1.6	<5	<5	36	29	165	120	Oct
Hawaii:	Honolulu	1.16	1.19	1.6	1.5	<5	<5	11	10	85	70	Nov
Idaho:	Idaho Falls	1.21	1.27	1.4	1.5	10	<5	34	30	205	140	Sep
Ill:	Chicago	1.16	1.17	1.5	1.5	<5	<5	19	22	130	100	Oct
Ind:	Indianapolis	1.20	1.16	1.5	1.5	<5	<5	25	23	110	90	Aug
Iowa:	Des Moines	1.22	1.22	1.4	1.4	5	5	30	27	100	85	Sep
Kans:	Wichita	1.19	1.16	1.4	1.4	5	<5	25	21	80	60	Nov
Ky:	Louisville	1.13	1.11	1.5	1.6	<5	<5	37	31	100	65	Sep
La:	New Orleans	1.18	1.18	1.5	1.6	<5	<5	59	52	180	125	Nov
Maine:	Portland	1.18	1.18	1.5	1.5	<5	<5	33	36	210	190	Sep
Md:	Baltimore	1.13	1.13	1.5	1.6	<5	<5	28	26	125	90	Sep
Mass:	Boston	1.18	1.15	1.6	1.5	<5	<5	38	41	245	210	Oct
Mich:	Detroit	1.17	1.13	1.5	1.5	<5	<5	21	21	120	110	Aug
	Grand Rapids	1.22	1.17	1.5	1.4	<5	<5	23	23	135	115	Sep
Minn:	Minneapolis	1.22	1.20	1.5	1.5	10	<5	37	34	160	140	Oct
Miss:	Jackson	1.22	1.22	1.5	1.5	<5	<5	53	40	125	90	Aug
Mo:	Kansas City	1.19	1.20	1.4	1.4	10	<5	32	32	100	65	Aug
	St. Louis	1.21	1.19	1.4	1.5	10	<5	28	29	95	70	Nov
Mont:	Helena	1.19	1.18	1.5	1.5	5	<5	32	27	195	130	Nov
Nebr:	Omaha	1.21	1.21	1.5	1.5	5	<5	30	30	105	80	Sep
Nev:	Las Vegas	1.20	1.19	1.5	1.5	<5	<5	10	8	90	55	Oct
N. H:	Manchester	1.19	1.19	1.5	1.6	<5	<5	33	36	250	250	Sep
N. J:	Trenton	1.16	1.11	1.5	1.4	<5	<5	23	23	135	105	Aug
N. Mex:	Albuquerque	1.19	1.19	1.5	1.5	5	<5	14	12	70	50	Nov
N. Y:	Buffalo	1.15	1.10	1.5	1.5	<5	<5	24	22	160	130	Aug
	New York	1.14	1.12	1.5	1.6	<5	<5	30	32	180	150	Oct
	Syracuse	1.16	[b] —	1.6	—	<5	—	23	—	160	—	Nov
N. C:	Charlotte	1.16	1.18	1.5	1.5	<5	<5	43	39	140	110	Nov
N. Dak:	Minot	1.20	1.18	1.5	1.5	15	15	72	63	175	185	Sep
Ohio:	Cincinnati	1.18	1.16	1.5	1.6	<5	<5	28	21	105	70	Aug
	Cleveland	1.18	1.12	1.5	1.5	<5	<5	25	23	135	115	Nov
Okla:	Oklahoma City	1.13	1.12	1.6	1.6	<5	<5	27	20	75	60	Oct
Ore:	Portland	1.26	1.23	1.4	1.4	10	5	40	33	190	205	Aug
Pa:	Philadelphia	1.17	1.12	1.5	1.6	<5	<5	25	21	140	105	Nov
	Pittsburgh	1.18	1.13	1.5	1.5	<5	<5	34	35	175	160	Nov
P. R:	San Juan	1.11	1.15	1.5	1.5	<5	<5	15	14	90	80	Nov
R. I:	Providence	1.17	1.13	1.5	1.5	<5	<5	27	25	180	165	Sep
S. C:	Charleston	1.16	1.16	1.5	1.6	<5	<5	35	27	145	100	Aug
S. Dak:	Rapid City	1.14	1.26	1.5	1.4	10	<5	48	62	155	165	Oct
Tenn:	Chattanooga	1.17	1.19	1.4	1.6	<5	<5	51	42	145	95	Oct
	Memphis	1.16	1.14	1.5	1.6	<5	<5	42	32	85	60	Sep
Tex:	Austin	1.11	1.12	1.6	1.4	<5	<5	10	8	45	25	Oct
	Dallas	1.12	1.14	1.5	1.6	<5	<5	22	18	70	50	Aug
Utah:	Salt Lake City	1.24	1.28	1.5	1.6	10	<5	30	28	195	180	Nov
Vt:	Burlington	1.18	1.11	1.5	1.5	<5	<5	30	29	190	150	Aug
Va:	Norfolk	1.13	1.13	1.5	1.6	<5	<5	28	25	110	90	Aug
Wash:	Seattle	1.21	1.22	1.5	1.4	10	<5	36	35	190	220	Oct
	Spokane	1.27	1.26	1.5	1.5	10	<5	29	30	155	140	Aug
W. Va:	Charleston	1.13	1.13	1.5	1.5	<5	<5	34	26	95	60	Oct
Wis:	Milwaukee	1.23	1.19	1.6	1.6	<5	<5	21	17	145	110	Sep
Wyo:	Laramie	1.22	1.20	1.4	1.4	15	<5	25	28	120	130	Sep
Network average		1.18	1.17	1.5	1.5	<5	<5	28.9	26.3	133	110	Nov 63

[a] The monthly average iodine-131 and barium-140 concentration at each station was <10 pc/liter.

[b] Dash indicates no sample collected

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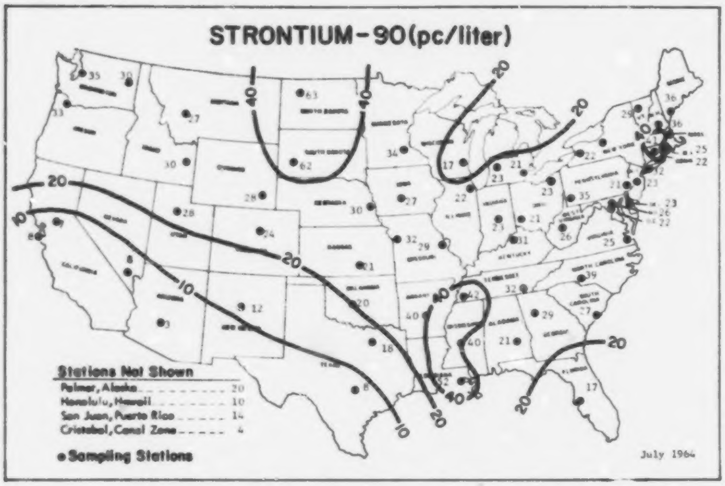
STRONTIUM-90(pc/liter)
Stations Not Shown
Palmer, Alaska 20
Honolulu, Hawaii 10
San Juan, Puerto Rico 14
Cristobal, Canal Zone 4
Sampling Stations
July 1964
40
20
10

FIGURE 1.—STRONTIUM-90 CONCENTRATIONS IN PASTEURIZED MILK, JULY 1964

TABLE 3.—DISTRIBUTION OF SAMPLING STATIONS IN VARIOUS RANGES OF RADIONUCLIDE CONCENTRATIONS IN MILK, JULY 1964

Strontium-89		Strontium-90		Iodine-131		Cesium-137		Barium-140	
(pc/liter)	Number of stations	(pc/liter)	Number of stations	(pc/liter)	Number of stations	(pc/liter)	Number of stations	(pc/liter)	Number of stations
<5	59	<1-9	3	<10	62	<5-45	4	<10	62
5	2	10-19	7			50-95	24		
10	0	20-29	30			100-145	21		
20	1	30-39	16			150-195	8		
		40-49	4			200-245	3		
		50-59	1			250-295	2		
		60-69	1						

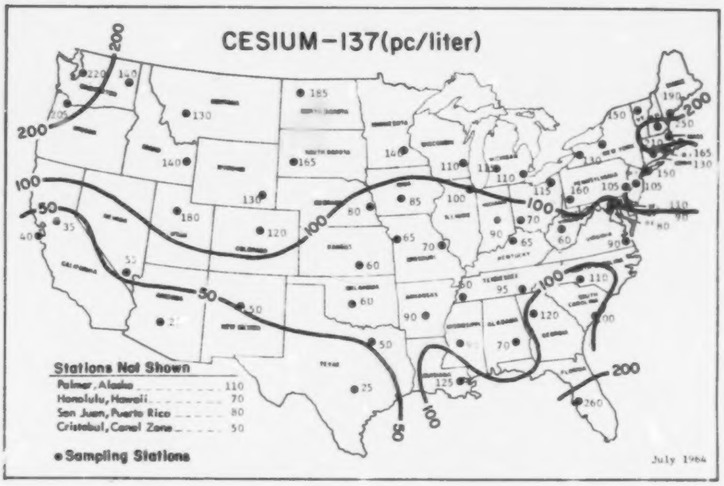
CESIUM-137(pc/liter)
Stations Not Shown
Palmer, Alaska 110
Honolulu, Hawaii 70
San Juan, Puerto Rico 80
Cristobal, Canal Zone 50
Sampling Stations
July 1964
200
100
50

FIGURE 2.—CESIUM-137 CONCENTRATIONS IN PASTEURIZED MILK, JULY 1964

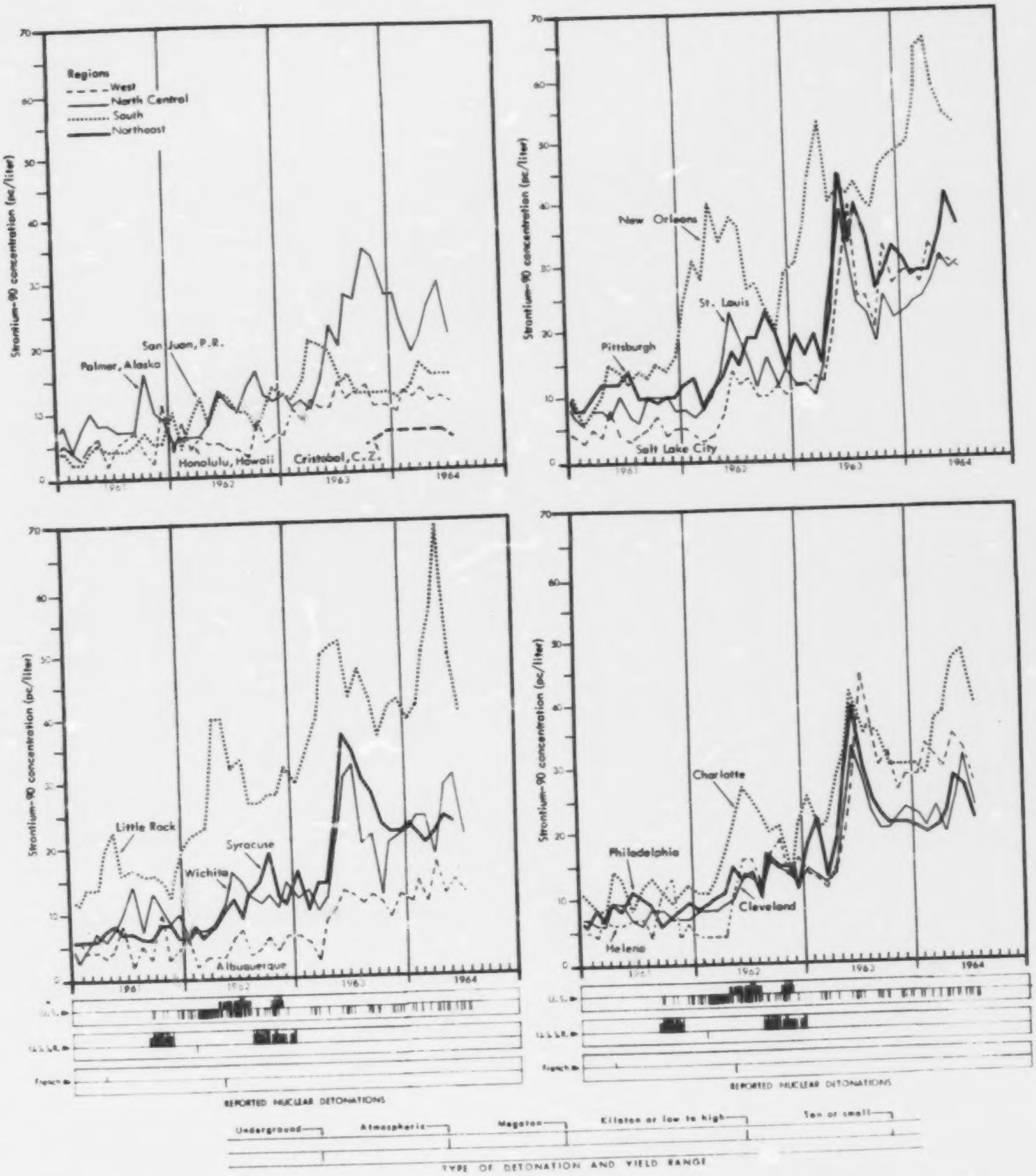

FIGURE 3.—STRONTIUM-90 IN PASTEURIZED MILK, 1961–JULY 1964

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in the sampling program are presented in figure 3. Each graph shows the strontium–90 concentrations in milk from one city in each of the four U.S. Bureau of Census regions. This method of selection permits graphic presentation of data for each city in the network three times a year. The last column in table 2 shows the most recent issue in which a graph of the strontium–90 concentration was given for each station. A tabulation of the network monthly maximum, minimum, and average radionuclide concentrations in milk was given for March 1960–March 1964 in the July 1964 issue of *RHD* (*2*).

Figure 4 is a graph of the pasteurized milk network monthly averages for strontium–89, strontium–90, iodine–131, and cesium–137 from January 1961 through July 1964. The following discussion relates to this graph.

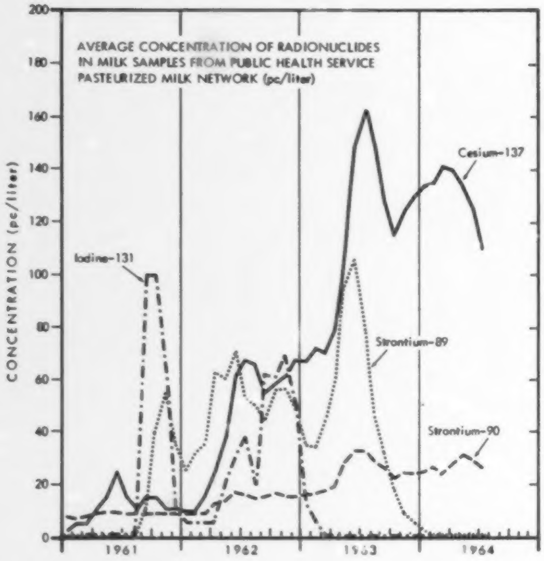

FIGURE 4.—NETWORK AVERAGE RADIONUCLIDE CONCENTRATIONS IN PASTEURIZED MILK

Strontium–90 concentrations in milk, which averaged about 10 pc/liter during 1961, gradually increased to 30 pc/liter by mid-1964. A peak extending into the high thirties during the spring and summer of 1963 is roughly 15 pc/liter above previous and subsequent averages.

Cesium–137 concentrations in milk averaged only about 5 pc/liter greater than strontium–90 concentrations during 1961. Unlike strontium–90, however, cesium–137 concentration increased rapidly to 60-70 pc/liter during the spring and summer of 1962. Again in the summer of 1963 cesium–137 in milk increased in concentration to 160 pc/liter. Thereafter, cesium–137 concentrations decreased to 120 pc/liter by July 1964. There was a decline in the cesium–137 concentrations during the summer of 1964 when concentrations dipped to about 115 pc/liter. In the three previous years the peak cesium–137 concentration occurred in mid-summer.

Iodine–131 concentrations in milk have been low or nondetectable except during September-December 1961 and May 1962 through January 1963. The maximum network average observed was 100 pc/liter.

The network average strontium–89 concentrations in milk rose above the minimum detectable limit of 5 pc/liter in October 1961 and remained there through 1962 and 1963. The maximum network average was 105 pc/liter. The variations in the network average which are apparent in figure 4 are due to such factors as the amount of nuclear testing and weather conditions as well as seasonal effects.

2. Indiana Milk Network July 1964

Bureau of Environmental Sanitation
Indiana State Board of Health

The Indiana State Board of Health began sampling pasteurized milk for radiological analysis in September 1961. Indiana was geographically divided into five major milksheds, and one large dairy within each milkshed was selected as a sampling station (figure 5).

The milk samples are routinely analyzed for iodine–131, cesium–137, barium–140, strontium–89 and strontium–90. Until August 1963, analyses for the gamma emitters iodine–131, cesium–137 and barium–140 were conducted on a weekly basis, except when iodine–131 exceeded 100 pc/liter, at which times the frequency of sampling was increased. Because of

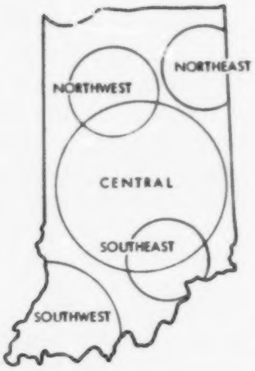

FIGURE 5.—INDIANA MILK SAMPLING LOCATIONS

continued low concentrations of the short-lived gamma emitters, the sampling frequency was reduced in August 1963 to once per month for the northeast, southeast and southwest milksheds. Strontium-89 and strontium-90 analyses are performed monthly for each station.

An ion exchange analytical procedure (*3*) is employed for strontium-89 and strontium-90 analyses. Minimum detectable levels for strontium-89 and strontium-90 are about 5 and 1 pc/liter, respectively. A 512-channel pulse height analyzer and shielded 4 x 4-inch sodium iodide crystal are used for the gamma analysis of iodine-131, cesium-137 and barium-140. Analyses of counting statistics indicate that the lower limit of detectability for both iodine-131 and barium-140 is 5 pc/liter. Cesium-137 analyses are subject to a 6 percent error at the 100 pc/liter level. Additional factors such as drift of the analyzer and calibration factors may increase these limits to a small extent.

The monthly averages of the data obtained for the individual sampling stations and the State averages are reported in table 4.

TABLE 4.—RADIONUCLIDES IN INDIANA MILK, JULY 1964 [a]

[Radionuclide concentrations in pc/liter]

Sampling location	Calcium (g/liter)	Potassium-40	Strontium-90	Cesium-137
Northeast	1.11	1,260	24	75
Southeast	1.12	1,330	25	70
Central	1.11	1,310	21	75
Southwest	1.12	1,320	22	70
Northwest	1.11	1,340	21	100
State average	1.11	1,310	23	80

[a] The monthly average iodine-131, barium-140, and strontium-89 concentrations at each station were zero.

3. New York Milk Network
May 1964

Division of Environmental Health Services
State of New York Department of Health

Milk samples collected routinely from six cities—Albany, Buffalo, Massena, Newburgh, New York City, and Syracuse (figure 6) are analyzed for their radionuclide content by the State of New York Department of Health. Pasteurized milk samples are collected daily and composited weekly for the determination of strontium-89, strontium-90, iodine-131, cesium-137 and barium-lanthanum-140 at all stations except Massena, where samples are composited bi-weekly, and at New York City where one daily milk sample representing the total milk supply for that day is obtained and analyzed once per week. Samples are obtained from processing plants except at Albany, where the daily sample is obtained from marketing point. During periods when cows are no longer on stored feed, the sample from Albany is analyzed daily for iodine-131. In the event that any city reports iodine-131 concentrations exceeding 100 pc/liter, increased surveillance is undertaken.

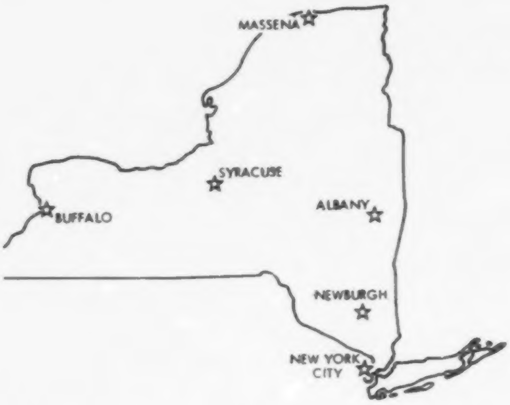

FIGURE 6.—NEW YORK MILK SAMPLING LOCATIONS

A matrix method (4) is used for the analysis of spectral data to determine the concentrations of gamma-emitting nuclides in milk. With this method, the individual nuclide contributions to the gamma spectrum are separated by solution of simultaneous equations describing the spectral interferences.

The analytical procedure for strontium-89 and strontium-90 is based on ion exchange methods. Cations (including radiostrontium) are eluted from the ion exchange resin with sodium chloride solution, strontium isotopes are gathered by means of sodium carbonate, isolated by means of ethylenediaminetetraacetic acid (EDTA), and radiostrontium is counted with a low background beta counter having an 0.8 mg/cm^2 window. The strontium-90 portion is differentially estimated by a second count 40 hours later to determine the rate of ingrowth of its daughter product yttrium-90. The monthly average radionuclide concentrations in milk are shown in table 5.

TABLE 5.—RADIONUCLIDES IN NEW YORK MILK, MAY 1964 [a]

[Average concentrations in pc/liter]

Sampling location	Strontium-89	Strontium-90	Cesium-137
Albany	<3	21	115
Buffalo	3	22	108
Massena	4	33	209
Newburgh	6	24	121
New York City	<3	25	118
Syracuse	4	25	108
Average	4	25	130

[a] The monthly average I^{131} and Ba-La^{140} (in equilibrium) at each station was less than the minimum detectable level (20 pc/liter).

4. Oregon Milk Network March-May 1964

Division of Sanitation & Engineering,
Oregon State Board of Health

The Oregon State Board of Health conducts milk monitoring at eight major milk-producing centers throughout the State of Orgeon, as shown in figure 7. Half-gallon samples of pasteurized packaged milk are collected Statewide on a monthly basis by the Oregon Department of Agriculture and weekly in the Portland area by the city of Portland. Milk sampling frequency is accelerated to a weekly schedule at those locations having radionuclide concentrations in milk in excess of 100 pc/liter for iodine-131 or 500 pc/liter for cesium-137. The samples are forwarded to the Oregon State Board of Health radiation laboratory for iodine-131, cesium-137, barium-140, and strontium-90 analyses. Gamma analyses are performed utilizing a 3" x 3" sodium iodide scintillation crystal detector with a 512-channel gamma spectrometer. Samples are normally counted for 100 minutes. The strontium-90 concentrations reported by the Oregon State Board of Health were analyzed using the trichloracetic acid analytical procedure (5) with the counting performed using a low background beta counter with a 2-inch detector. The minimum detectable concentrations for iodine-131, cesium-137, and barium-140 are 15 pc/liter. The minimum detectable concentration is defined to be that amount of activity which, in the same counting time, gives a count that differs from the background count by 3 times the standard deviation (σ) of the background count.

TABLE 6.—RADIONUCLIDE CONCENTRATIONS IN OREGON MILK, MARCH-MAY 1964 [a]

[Average concentrations in pc/liter]

Sampling location & frequency	Nuclide	March	April	May
Baker Monthly	Strontium-90 Cesium-137	33 165	30 155	35 185
Coos Bay Monthly	Strontium-90 Cesium-137	[b] — —	84 260	53 190
Eugene Monthly	Strontium-90 Cesium-137	28 130	31 120	19 160
Medford Monthly	Strontium-90 Cesium-137	28 140	29 175	18 85
Nyssa Monthly	Strontium-90 Cesium-137	28 135	18 110	23 125
Portland composite Weekly	Strontium-90 Cesium-137	20 146	30 185	37
Portland local producer Weekly	Strontium-90 Cesium-137	27 173	32 170	50 197
Redmond Monthly	Strontium-90 Cesium-137	26 160	25 180	18 105
Tillamook Weekly	Strontium-90 Cesium-137	34 180	41 175	73 388

[a] [illegible]-131 and barium-140 concentrations were below lower limit of detection of 15 pc/liter. In some cases unidentified activity having a half life of about 5 days (suggested to be radon) interfered with some iodine-131 analyses.

[b] Dash indicates no analysis performed.

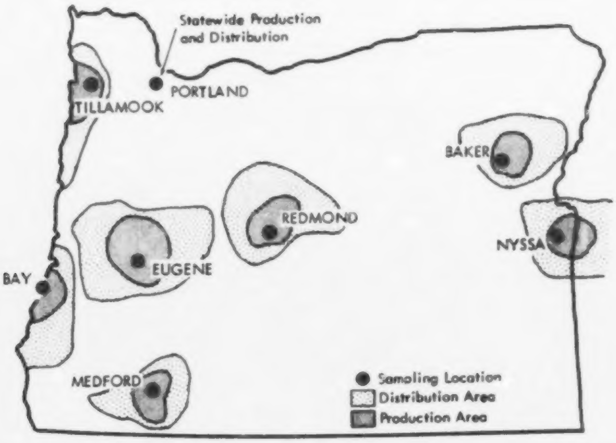

FIGURE 7.—OREGON PASTEURIZED MILK NETWORK SAMPLING LOCATIONS SHOWING PRODUCTION AND DISTRIBUTION AREAS

Table 6 presents the Oregon milk surveillance data for the period March through May 1964. The Portland composite sample represents contributions from nearly all milksheds in Oregon, plus some in southern Washington. Thus, it tends to represent a State average.

5. Canadian Milk Network [3]
1964

Radiation Protection Division
Department of National Health and Welfare,
Ottawa, Canada

The Radiation Protection Division of the Department of National Health and Welfare began monitoring milk for strontium-90 in November 1955. At first analyses were carried out on samples of powdered milk obtained from processing plants. However, since January 1963 liquid whole milk has been analyzed instead. With this change, more representative samples of milk consumed can be obtained, and in addition it is possible to choose milk sampling locations (see figure 8) in the same areas as the air and precipitation stations. At present, the analyses include determinations of iodine-131, strontium-89, cesium-137, and strontium-90 as well as stable potassium and calcium.

The milk samples are obtained through the cooperation of the Marketing Division of the Canadian Department of Agriculture. At each station samples are collected three times a week from selected dairies and are combined into weekly composites and forwarded to the radiochemical laboratory in Ottawa. The contribution of each dairy to the composite sample is directly proportional to its volume of sales. In most cases a complete sample represents over 80 percent of the milk processed and distributed in the area. Several of the weekly samples are randomly selected and analyzed for iodine-131. The results of the spot checks for iodine-131 will not be reported unless there is evidence that the levels are rising. A monthly composite of the samples is analyzed for strontium-90, cesium-137, and stable potassium and calcium.

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[3] Data from *Radiation Protection Programs, Vol. 2, No. 8:* 25-30, Radiation Protection Division, Canadian Department of National Health and Welfare (July 1964).

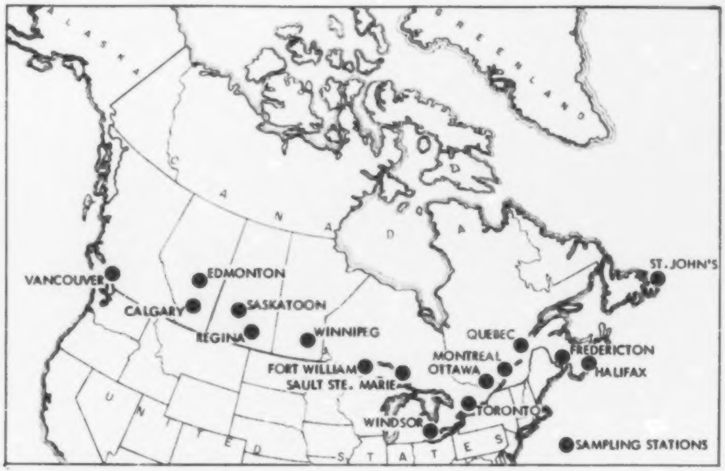

FIGURE 8.—CANADIAN MILK SAMPLING STATIONS

Analytical Methods

Radiochemical methods are used for the analysis of iodine-131 (*6*). For the analysis of radiostrontium, carrier strontium is added to a one-liter sample of milk, and the milk is then placed in a tray lined with a polyethylene sheet and evaporated under infra-red lamps. The residue is ashed in a muffle furnace at 450° C, dissolved in dilute nitric acid, and strontium separated by fuming nitric acid precipitation. The combined strontium-89 and strontium-90 are determined by counting in a low background beta counter. Strontium-90 is determined separately by extracting and counting the yttrium-90 daughter while strontium-89 is estimated by difference from the total radiostrontium measurement. Appropriate corrections are made for self-absorption and counter efficiency at all stages. Calcium is determined by flame photometry.

Cesium-137 is determined by gamma spectroscopy using a scintillation crystal and a multi-channel pulse height analyzer. A sample consisting of 4.5 liters of milk is placed in a sample tray constructed in the form of an inverted well to accommodate the 5- x 4-inch sodium iodide crystal detector. The sample is counted for 100 minutes and the gamma spectrum recorded. Estimates are made of the potassium-40 and cesium-137 content of the milk by comparison of the spectrum with the spectra of standard preparations of these two radionuclides. With this method the pottassium-40 concentration is determined and the Compton contribution of this radionuclide to the cesium-137 photopeak is subtracted to obtain the cesium-137 concentration. The stable potassium content is estimated from the potassium-40 concentration.

Sources of Error

In the iodine and strontium determinations, tests indicate that the statistical error (95 percent confidence level) in the chemical operations involved is about plus-or-minus 10 percent. This value is independent of the concentration of the radioisotope in the milk because it depends only on the recovery of the carrier. In the determination of cesium-137 this factor is not involved.

The chemical procedures error must be combined with the counting error which depends primarily on the concentration of the nuclide in the sample, the background radiation, and the length of time the sample and background are counted. This counting error has been evaluated mathematically for the particular counting arrangement used.

The overall errors, estimated on the basis indicated above, are given in table 7.

TABLE 7.—TOTAL ERROR FOR VARIOUS RADIONUCLIDE CONCENTRATIONS IN MILK[a]

Nuclide	Error for 10 pc/liter	Error for 50 pc/liter	Error for 100 pc/liter
Strontium-89	±25%	±20%	±15%
Strontium-90	±15%	±10%	±10%
Iodine-131	±50%	±20%	±10%
Cesium-137	±60%	±25%	±10%

[a] All errors are 2σ values, representing 95 percent confidence levels.

TABLE 8.—RADIONUCLIDES IN CANADIAN WHOLE MILK, JUNE 1964

[Radionuclide concentration in pc/liter]

Station	Calcium (g/liter)	Potassium (g/liter)	Strontium-90	Cesium-137
Calgary	1.13	1.6	30.7	142
Edmonton	1.13	1.5	32.1	160
Ft. William	1.13	1.7	46.1	238
Fredericton	1.10	1.7	46.9	297
Halifax	1.15	1.7	57.7	346
Montreal	1.08	1.7	29.3	154
Ottawa	1.10	1.6	25.5	139
Quebec	1.10	1.6	47.2	251
Regina	1.10	1.7	36.4	146
St. John's, Nfld	1.08	1.6	73.0	402
Saskatoon	1.10	1.6	31.2	126
Sault Ste. Marie	1.08	1.6	44.0	233
Toronto	1.10	1.6	15.4	103
Vancouver	1.17	1.6	48.1	373
Windsor	1.08	1.6	16.0	95
Winnipeg	1.08	1.7	26.4	135
Average	1.11	1.6	37.9	209

Results

Table 8 presents monthly averages of strontium-90, cesium-137 and stable calcium and potassium in Canadian whole milk. Spot checks for iodine-131 and strontium-89 indicate that all samples had <5 pc/liter.

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MOVING ANNUAL AVERAGE RADIONUCLIDE CONCENTRATIONS IN PASTEURIZED MILK, AUGUST 1963–JULY 1964

Division of Radiological Health, Public Health Service

Radionuclide concentration values reported by the Pasteurized Milk Network (*1*) can be used to estimate the contribution of milk to a population's radiation exposure. This is done by determining both the annual average concentrations of specific radionuclides in milk and the average daily milk consumption of a representative individual in a suitable sample of the population.

The data listed in table 1 are concerned with the first of these requirements, *i.e.*, annual average concentrations of strontium-89, strontium-90, and cesium-137 in one liter of pasteurized milk. Limited data are available for estimating the average daily milk consumption (on a volume basis) for specific age groups in the U.S. population (*2, 3*).

To arrive at a basis of comparison between the daily rates of intake of the radionuclides from the milk component of the diet and the Federal Radiation Council's ranges of transient daily rates if intake (*4*), it is assumed that the average daily milk consumption of an individual in a population group is one liter. The Guides, however, apply to total intake from all

TABLE 1.—MOVING ANNUAL AVERAGE RADIONUCLIDE CONCENTRATIONS IN MILK[a b]

[Concentrations in pc/liter]

Sampling locations		Strontium-89		Strontium-90		Cesium-137	
		July 1963–June 1964	August 1963–July 1964	July 1963–June 1964	August 1963–July 1964	July 1963–June 1964	August 1963–July 1964
Ala:	Montgomery	14	10	23	23	91	89
Alaska:	Palmer	20	16	26	26	164	164
Ariz:	Phoenix	3	3	4	4	26	26
Ark:	Little Rock	31	21	46	46	157	151
Calif:	Sacramento	5	4	9	9	56	55
	San Francisco	8	6	11	10	65	63
Colo:	Denver	14	10	20	20	94	93
Conn:	Hartford	13	10	25	24	182	173
Del:	Wilmington	12	9	26	26	145	140
D. C:	Washington	15	9	20	20	99	94
Fla:	Tampa	9	7	15	15	246	246
Ga:	Atlanta	23	15	33	33	159	149
Hawaii:	Honolulu	6	5	11	11	83	82
Idaho:	Idaho Falls	27	18	30	29	189	183
Ill:	Chicago	10	7	21	21	128	124
Ind:	Indianapolis	13	9	23	23	110	108
Iowa:	Des Moines	19	13	27	27	98	98
Kans:	Wichita	14	9	23	22	75	72
Ky:	Louisville	30	19	35	34	113	106
La:	New Orleans	25	16	50	50	161	157
Maine:	Portland	19	14	35	34	242	233
Md:	Baltimore	19	12	23	23	123	116
Mass:	Boston	22	16	38	37	271	265
Mich:	Detroit	10	8	20	20	127	126
	Grand Rapids	11	9	22	22	138	136
Minn:	Minneapolis	27	19	35	35	168	163
Miss:	Jackson	26	16	41	42	120	116
Mo:	Kansas City	21	15	29	30	90	89
	St. Louis	17	11	24	24	93	90
Mont:	Helena	27	16	33	31	217	205
Nebr:	Omaha	21	14	28	28	106	102
Nev:	Las Vegas	10	8	12	11	87	83
N. H:	Manchester	19	14	36	35	286	276
N. J:	Trenton	12	9	21	21	137	130
N. Mex:	Albuquerque	8	6	12	12	58	56
N. Y:	Buffalo	13	9	23	23	161	159
	New York	19	13	32	31	193	190
	Syracuse	15	11	24	24	161	161
N. C:	Charlotte	25	15	35	35	129	123
N. Dak:	Minot	38	24	61	61	163	162
Ohio:	Cincinnati	14	9	26	25	104	100
	Cleveland	13	8	23	22	125	124
Okla:	Oklahoma City	16	10	24	24	82	78
Ore:	Portland	21	15	33	33	177	178
Pa:	Philadelphia	12	7	23	22	136	132
	Pittsburgh	18	11	32	32	171	168
P. R:	San Juan	11	7	13	13	80	77
R. I:	Providence	14	9	28	27	191	184
S. C:	Charleston	13	7	30	31	140	135
S. Dak:	Rapid City	35	23	45	45	169	166
Tenn:	Chattanooga	33	20	43	42	149	136
	Memphis	22	13	34	33	87	81
Tex:	Austin	7	4	10	9	47	45
	Dallas	12	8	21	20	76	74
Utah:	Salt Lake City	22	15	28	27	194	187
Vt:	Burlington	18	13	31	30	213	206
Va:	Norfolk	14	9	23	23	106	102
Wash:	Seattle	22	15	29	29	167	167
	Spokane	23	16	31	30	155	152
W. Va:	Charleston	26	16	30	29	102	95
Wis:	Milwaukee	10	7	20	19	143	141
Wyo:	Laramie	20	14	23	22	118	117
Network average		18	12	26.8	26.4	136	132

[a] Annual averages were computed on basis of 52 weekly averages.
[b] Annual averages for iodine-131 and barium-140 at each station were <10.

sources. The upper limits of Range II correspond to the Radiation Protection Guide (RPG) for iodine–131 and to one-third of the RPG for radioactive strontium. The Guides are, for administrative reasons, expressed as a yearly radiation dose, but are based on lifetime exposure (*5*). The FRC emphasizes that the annual acceptable risk or exposure dose is not a dividing line between safety and danger in actual radiation situations (*6*).

Annual averages of radionuclide concentrations in milk sampled by the PHS Pasteurized Milk Network are presented in table 1. The data in table 1 are calculated as follows: Results from all samples collected in each week (Sunday through Saturday) are averaged, and the averages for all weeks terminating in each of twelve consecutive months are averaged to obtain the annual average.[1] To obtain the annual average daily intake (pc/day) of radionuclides from milk, the annual average concentration values (pc/liter) in table 1 must be multiplied by the annual average daily consumption (liters/day) of milk.

Monthly variations of radionuclide concentrations in milk are influenced by a number of combined causes such as weather conditions and dairying practices. The moving yearly average (table 1), obtained by updating the previous twelve-month average by one month, shows variations averaged over the year and tends to minimize purely seasonal variations. This method, therefore, shows trends over a considerable period of time.

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[1] Beginning with the October 1963 data, iodine-131 values of <10 pc/liter are considered to be zero for averaging purposes; previously, 5 pc/liter was used for calculating the averages.

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STRONTIUM-90 CONTENT OF HUMAN FOOD AND ANIMAL FEED IN 1962 AND 1963

Division of Pharmacology
Food and Drug Administration

This report summarizes the findings of strontium–90 in human food and animal feeds harvested during 1962 and 1963. In contrast to the first resume report that appeared in the September 1963 *RHD* in which strontium–90 levels in food were compared in pre- and post-atmospheric testing situations, this report attempts to assess the levels during 1962 and 1963 and to evaluate the trends. On the basis of meteorological prognostications, it was expected that foods harvested in 1962 would clearly reflect the impact of atmospheric testing. However, the findings in the September 1963 *RHD* resume report showed no extensive increase in fallout in foods harvested in the immediate post testing period that extended through 1962. In retrospect, it can now be seen that the prediction of a heavy fallout peak for the spring of 1962 erred on the high side by a considerable margin. There is evidence that a sizeable inventory of strontium–90 still exists in the atmosphere, but that the rate at which this reaches the earth's surface may be slower than was anticipated. Thus instead of a sharp peak in 1962, it is expected that contamination will be spread out over a number of years and decline slowly.

This report represents a collation of 3,839 strontium-90 analyses made by 10 Food and Drug District Laboratories during 1962 and 1963. It does not include cesium-137 results because the numbers of analyses are too limited to be effectively interpreted. Quarterly analyses of total diet for strontium-90 and cesium-137 have been reported elsewhere. For details of sampling and analytical procedures, refer to the resume report in the September 1963 *RHD* (*1*).

Results

Table 1 gives the strontium-90 content of twelve food groups arranged to identify harvest years 1962 and 1963. With two minor exceptions (sea food and spices) the strontium-90 content of all food groups harvested in 1963 is higher. In some categories the rise is noteworthy, as exemplified by animal feeds and grains. In some groups where the disparity in number of samples in the two comparison periods is very great, caution should be used in the overall interpretation, limiting this merely to an indication of trends. (*cf.* root vegetables, fruits, tea, coffee, etc.)

Tables 2 through 7 list in detail the strontium-90 content of five of the products: vegetables, root vegetables, fruits, grains and animal feeds. Here again, because of disparity in numbers of some varieties compared, trends can merely be indicative. However, in such items as lettuce, spinach, soybeans and cabbage (table 2) where the number of samples compared at least approaches the same order of magnitude, it can be seen that the increases in strontium-90 in 1963 are small. Similar trends may be noted in beets and carrots, (table 3) but a notable exception is white potatoes, where the increase has been more than three-fold. In the case of fruits sizeable increases are observed in strawberries, peaches and apples. In the grains, (table 5) the three-to four-fold increases in oats, wheat and barley are striking. The relatively low strontium-90 content of corn which has received frequent comment in the past, does not, however, indicate any upward trend in 1963; unfortunately, the numbers of samples examined in the two seasons are rather small. Table 6 points up the fact that the animal feeds, peanut hay, lespedeza hay and alfalfa, important sources of strontium-90 in the food chain, had sizable increases in the harvest year 1963.

TABLE 1.—STRONTIUM-90 CONTENT OF HUMAN FOODS AND ANIMAL FEEDS

[Concentrations in pc/kg]

Product	1962 Harvest				1963 Harvest			
	No. of varieties	No. of samples	Average	Range	No. of varieties	No. of samples	Average	Range
Animal feed	7	168	350	0.5—1700	5	102	1080	17 —6800
Coffee		114	16	0.9— 90		28	39	1.7— 99
Dairy products		72	118	4.8—1040		106	219	6.2— 736
Eggs		35	2.7	0.2— 9		8	5.2	2.6— 11
Fruits	17	541	5.2	0.0— 103	10	147	19	0.0— 102
Grains	6	271	66	0.5— 495	6	167	247	0.4—1340
Nuts	6	85	52	0.0— 292	3	36	144	0.5— 543
Root vegetables	7	352	12	0.0— 494	7	96	14	0.3— 157
Sea food	12	201	2.0	0.0— 43	3	10	1.0	0.1— 4.3
Spices	12	93	549	0.8—4400	3	7	199	1.7— 706
Tea		158	386	19 —2290		30	778	39 —4060
Vegetables	16	643	36	0.0— 927	14	369	45	0.4— 598

It seemed of interest to determine whether the place of growth and harvest of foods within the continental U.S.A. would influence the levels of strontium-90. Three areas were selected, and all those foods having representation in number of samples of approximately the same order were tabulated. The areas are as follows:

TABLE 2.—STRONTIUM-90 CONTENT OF VEGETABLES

[Concentrations in pc/kg]

Variety	1962 Harvest			1963 Harvest		
	No. of samples	Average	Range	No. of samples	Average	Range
LEAFY						
Celery	74	12	0.7— 60	62	20	0.9—118
Collards	21	210	10 —688	9	49	5.0—201
Kale	5	121	22 —237	5	16	4.7— 27
Lettuce	125	17	0.1—178	120	22	1.1—141
Mustard greens	2	69	47 — 91	2	164	111 —217
Parsley	38	74	5.0—178	1	88	
Spinach	36	57	5.3—198	42	88	3.1—228
Turnip greens	9	222	2.8—927	1	484	
LEGUMES						
Peas	50	11	0.0— 53	2	11	7.2— 15
Soybeans	62	75	1.2—693	59	112	2.7—598
BRASSICAE						
Broccoli	28	33	0.7—244	2	2.3	1.3— 3.4
Brussel sprouts	6	5.7	0.7— 7.8			
Cabbage	127	13	0.3— 68	56	17	0.4—153
Cauliflower	30	4.6	0.5— 14			
MISCELLANEOUS						
Artichokes	6	21	1.4— 38	2	7.2	7.1— 7.2
Asparagus	24	2.0	0.2— 12	6	2.5	1.2— 3.4

Western States	Central States	Eastern States
Arizona	Alabama	Connecticut
California	Arkansas	Delaware
Colorado	Illinois	Florida
Idaho	Indiana	Georgia
Montana	Iowa	Maryland
Nevada	Kansas	Maine
New Mexico	Kentucky	Massachusetts
Oregon	Louisiana	New Hampshire
Utah	Michigan	New Jersey
Washington	Minnesota	New York
	Mississippi	North Carolina
	Missouri	Pennsylvania
	Nebraska	Rhode Island
	North Dakota	South Carolina
	Ohio	Vermont
	Oklahoma	Virginia
	South Dakota	West Virginia
	Tennessee	
	Texas	
	Wisconsin	

Table 7 shows the results of this arrangement. First, it can be seen that there is a clear trend, both in 1962 and 1963, for contamination to be lowest in the Western Region, highest in the Central Region, and intermediate in the Eastern region. Second, it can be seen that the individual averages for all products are higher in 1963 than in 1962. It follows therefore that the ratio of strontium-90 in 1963 to strontium-90 in 1962 is greater than unity. It is of interest, however, to observe that the average strontium-90 increase in 1963 has been highest in the West and lowest in the East. (See grand average of ratios table 7.) Statistical analyses show that the level of significance is 90 percent, indicating a well-defined trend.

The regional comparisons for 5 products (wheat, cabbage, potatoes, strawberries and alfalfa) are illustrated in figure 1.

Conclusions

1. There is a clear indication that the levels of strontimum-90 contamination in foodstuffs have risen in 1963 over 1962.
2. In both 1962 and 1963, the highest levels of strontium-90 were observed in the Central States and the lowest were observed in the Western States.

TABLE 3.—STRONTIUM-90 CONTENT OF ROOT VEGETABLES

[Concentrations in pc/kg]

Variety	1962 Harvest			1963 Harvest		
	No. of samples	Average	Range	No. of samples	Average	Range
Beets	60	15	0.7—101	38	17	0.4— 64
Carrots	79	7.6	0.3— 52	38	17	0.4— 64
Onions	48	8.1	0.0— 70	6	10	4.6— 26
Radishes	33	10	0.6— 92	1	22	
Sweet potatoes	38	39	2.3—494	3	9.0	1.8— 14
Turnips	19	11	0.9— 42	1	4.6	
White potatoes	75	2.3	0.0— 6.4	42	10	0.3—157

TABLE 4.—STRONTIUM-90 CONTENT OF FRUITS

[Concentrations in pc/kg]

Variety	1962 Harvest			1963 Harvest		
	No. of samples	Average	Range	No. of samples	Average	Range
Apples	50	2.3	0.1— 9.5	26	8.4	0.7— 22
Apricots	7	1.5	0.7— 2.9			
Cantaloupe	15	2.9	0.1— 24			
Cherries	59	5.3	0.2— 16	3	15	11 — 20
Cranberries	9	44	12 —103			
Cucumbers	39	5.8	0.4— 20			
Grapes	43	7.6	0.4— 50	4	33	16 — 56
Oranges	13	9.3	1.5— 27	3	11	1.9— 29
Peaches	43	5.2	0.2— 14	37	16	2 — 99
Pears	29	5.0	0.0— 14	3	21	4.6— 31
Peppers	27	2.3	0.1— 7.9			
Plums	29	2.1	0.3— 6.6			
Pumpkins	29	7.0	0.0— 40	2	9.6	8.1— 11
Squash	54	6.2	0.2— 34	3	6.1	1.8— 13
Strawberries	21	14	0.8— 42	45	32	2.7—102
Tomatoes	64	2.6	0.0— 9.0	21	6.5	0.0— 38
Watermelons	10	3.3	0.2— 15			

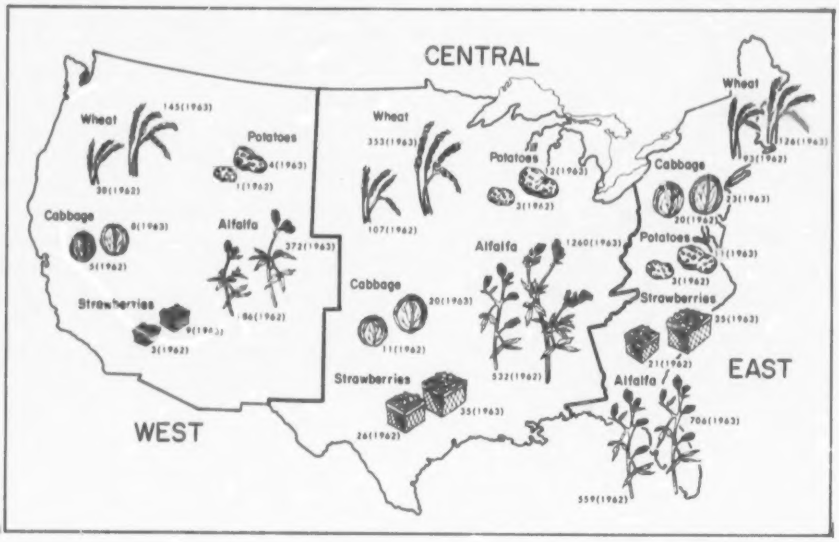
CENTRAL
WEST
EAST
Wheat
145(1963)
30(1962)
Potatoes
4(1963)
1(1962)
Cabbage
8(1963)
5(1962)
Alfalfa
372(1963)
186(1962)
Strawberries
9(1963)
3(1962)
Wheat
353(1963)
107(1962)
Potatoes
12(1963)
3(1962)
Alfalfa
1260(1963)
532(1962)
Cabbage
20(1963)
11(1962)
Strawberries
35(1963)
26(1962)
Wheat
126(1963)
93(1962)
Cabbage
23(1963)
20(1962)
Potatoes
11(1963)
3(1962)
Strawberries
35(1963)
21(1962)
Alfalfa
706(1963)
559(1962)

FIGURE 1.—STRONTIUM-90 CONTENT (pc/kg) OF FIVE SELECTED CROPS BY REGION, 1962–1963

TABLE 5.—STRONTIUM-90 CONTENT OF GRAINS

[Concentrations in pc/kg]

Variety	1962 Harvest			1963 Harvest		
	No. of samples	Average	Range	No. of samples	Average	Range
Barley	31	53	1.5—129	26	244	21 —868
Corn	31	2.5	0.5— 15	7	2.5	0.4— 5.2
Oats	38	61	0.9—187	20	173	10 —609
Rice	14	41	6.9—213	6	323	117 —544
Rye	19	103	6.2—255	19	212	13 —966
Wheat	138	83	1.4—495	89	286	4.0— 40

95

TABLE 6.—STRONTIUM-90 CONTENT OF ANIMAL FEEDS

[Concentrations in pc/kg]

Variety	1962 Harvest			1963 Harvest		
	No. of samples	Average	Range	No. of samples	Average	Range
Alfalfa	100	447	21 —1700	79	916	17—6860
Beet pulp	19	17	1.0— 196			
Corn ensilage	16	91	6.0— 378			
Cotton seed meal	10	23	0.5— 156			
Lespedeza hay	7	632	75 —1270	6	2427	178—3870
Peanut hay	9	740	25 —1040	15	1505	84—4320
Sorghum	7	117	9.0— 354	2	23	17— 28

TABLE 7.—REGIONAL CHANGES IN STRONTIUM-90 CONTENT OF PRODUCTS 1962 AND 1963 HARVEST

	Western States			Central States			Eastern States		
	1962	1963	Ratio [a]	1962	1963	Ratio [a]	1962	1963	Ratio [a]
ALFALFA									
No. of samples	27	18		44	41		29	20	
Average [b]	186	372	2.0	532	1257	2.4	559	706	1.3
APPLES									
No. of samples	14	8		15	10		21	8	
Average	0.9	4.0	4.5	2.8	11	3.9	3.0	9.4	3.1
CABBAGE									
No. of samples	26	19		48	25		53	14	
Average	5.0	8.0	1.6	11	20	1.8	20	23	1.1
CARROTS									
No. of samples	32	13		26	11		21	14	
Average	2.3	7.4	3.2	8.5	18	2.1	15	24	1.6
CELERY									
No. of samples	23	20		11	13		40	29	
Average	4.7	14	3.0	7.0	20	2.9	17	35	2.1
LETTUCE									
No. of samples	46	64		18	12		61	44	
Average	11	13	1.2	22	40	1.8	20	29	1.5
PEACHES									
No. of samples	10	10		9	11		24	16	
Average	1.7	5.1	3.0	9.4	25	2.7	5.1	17	3.3
SPINACH									
No. of samples	12	15		8	12		16	15	
Average	77	88	1.3	72	114	1.6	33	66	2.0
STRAWBERRIES									
No. of samples	10	5		5	24		6	16	
Average	3.0	9.1	3.0	26	35	1.4	21	35	1.7
TOMATOES									
No. of samples	17	8		20	7		21	6	
Average	0.5	2.6	4.9	2.2	4.9	2.2	4.9	14	2.9
WHEAT									
No. of samples	41	10		80	62		17	17	
Average	30	145	4.8	107	353	3.3	93	126	1.4
WHITE POTATOES									
No. of samples	23	9		26	22		26	11	
Average	1.0	4.4	4.4	2.8	12	4.3	2.9	11	3.8
Grand average of concentrations	29	55		108	313		66	100	
Grand average of ratios			3.1			2.5			2.1

[a] Ratio$=\frac{\text{Strontium-90 in 1963}}{\text{Strontium-90 in 1962}}$

[b] Units for all average values: picocuries strontium-90 per kilogram.

3. By region, the smallest rise in strontium-90 content of foodstuffs in 1963 over 1962 was in the East.
4. Within the frame of reference indicated by the Federal Radiation Council, this survey has uncovered no foods which, on the basis of daily intake of strontium-90, would approach, much less exceed the suggested daily limits of intake.

REFERENCE

(1) Laug, E. P.: Temporal and Geographical Distributions of Strontium-90 and Cesium-137 in Food (1960-1962), *Radiological Health Data 4:* 448-54 (September 1963).

Section III—Water

GROSS RADIOACTIVITY IN SURFACE WATERS OF THE UNITED STATES, MAY 1964

Division of Water Supply and Pollution Control, Public Health Service

Levels of radioactivity in surface waters of the United States have been monitored by the Public Health Service Water Pollution Surveillance System since its initiation in 1957. Beginning with the establishment of 50 sampling points, this system has expanded to 130 stations as of October 1, 1964. These are operated jointly with other Federal, State, and local agencies, and industry. Samples are taken from surface waters of all major U. S. river basins for physical, chemical, biological and radiological analyses. These data can be used for evaluating sources of radioactivity which may affect specific domestic, commercial, and recreational uses of surface water. Further, the system provides background information necessary for recognizing pollution and water quality trends and for determining levels of radioactivity to which the population may be exposed. Data assembled through the system and exact locations of sampling points are published in annual compilations (*1–7*).

Sampling Procedures

The participating agencies collect one-liter "grab" samples each week and ship them "as is" to the Surveillance System Laboratory in Cincinnati for analysis. Gross alpha and gross beta radioactivity determinations on the suspended and dissolved solids are performed as frequently as deemed necessary.

Presently, gross alpha and beta determinations are made on monthly composites of the weekly samples received from most stations. Weekly alpha and beta determinations are scheduled for stations located downstream from known potential sources of radioactive waste. Weekly analyses are also conducted at all newly established stations for the first year of operation.

Normally, samples are counted within two weeks following collection or within one week after compositing. The decay of activity is followed on each sample for which the first analysis shows unusually high activity. Also, if a recount indicates that the original analysis was questionable, values based on recounting are recorded. All results are reported for the time of counting and are not extrapolated to the time of collection.

Analytical Methods

The analytical method used for determining gross alpha and beta radioactivity is described in the eleventh edition of "Standard Methods for the Examination of Water and Wastewater" (*8*). Suspended and dissolved solids are separated by passing the sample through a membrane filter (type HA) with a pore size of 0.45 micron. Planchets are then prepared for counting the dissolved solids (in the filtrate)

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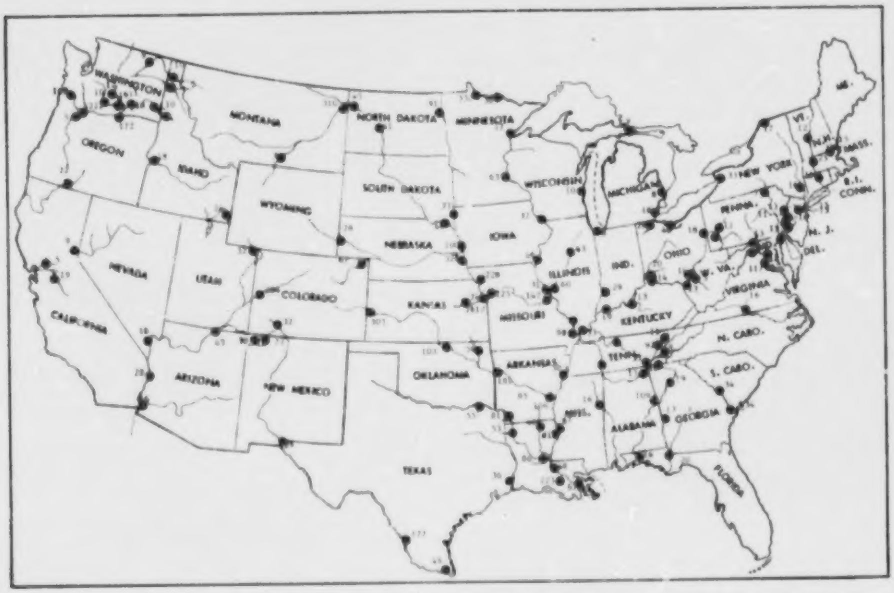
Table 1.—RADIOACTIVITY IN RAW SURFACE WATERS, MAY 1964

[Average concentrations in pc/liter]

Station	Beta activity			Alpha activity		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Allegheny River:						
Pittsbugh, Pa	3	8	11	1	1	2
Animas River:						
Cedar Hill, N. Mex	56	16	72	5	1	6
Apalachicola River:						
Chattahoochee, Fla	7	13	20	0	0	0
Arkansas River:						
Coolidge, Kansas	223	82	305	31	28	59
Ponca City, Okla	72	31	103	4	1	5
Fort Smith, Ark	99	82	181	9	2	11
Little Rock, Ark	60	25	85	5	1	6
Pendleton Ferry, Ark	73	33	106	5	0	5
Atchafalaya River:						
Morgan City, La	195	28	223	48	0	48
Bear River:						
Preston, Idaho	0	24	24	0	2	2
Big Horn River:						
Hardin, Mont	375	42	417	56	6	62
Big Sioux River:						
Sioux Falls, S. Dak	19	58	77	0	5	5
Chattahoochee River:						
Atlanta, Ga	12	7	19	1	0	1
Columbus, Ga	100	9	109	11	0	11
Lanett, Ala	6	7	13	1	0	1
Chena River:						
Fairbanks, Alaska	5	14	19	1	0	1
Clearwater River:						
Lewiston, Idaho	11	7	18	1	0	1
Clinch River:						
Clinton, Tenn	3	8	11	0	<1	<1
Kingston, Tenn	7	85	92	0	0	0
Colorado River:						
Loma, Colo	253	31	284	28	3	31
Page, Ariz	4	39	43	<1	13	13
Boulder City, Nev	2	14	16	0	8	8
Parker Dam, Calif-Ariz	1	27	28	0	8	8
Yuma, Ariz	3	43	46	0	4	4
Columbia River:						
Northport, Wash	2	7	9	0	1	1
Wenatchee, Wash	4	8	12	0	0	0
Pasco, Wash	428	1,183	1,611	<1	<1	<1
McNary Dam, Ore	41	131	172	0	1	1
Bonneville, Ore	38	184	222	0	0	0
Clatskanie, Ore	44	103	147	1	1	2
Connecticut River:						
Wilder, Vt	0	12	12	0	2	2
Northfield, Mass	13	12	25	0	0	0
Enfield Dam, Conn	3	10	13	0	0	0
Cuyahoga River:						
Cleveland, Ohio	10	38	48	0	1	1
Delaware River:						
Martins Creek, Pa	3	10	13	0	0	0
Trenton, N. J	3	8	11	0	0	0
Philadelphia, Pa	10	8	18	1	0	1
Escambia River:						
Century, Fla	5	8	13	0	0	0
Great Lakes:						
Duluth, Minn	6	11	17	0	0	0
Sault Ste. Marie, Mich	0	9	9	0	0	0
Milwaukee, Wisc	2	8	10	0	0	0
Gary, Ind	3	5	8	0	0	0
Port Huron, Mich	1	7	8	0	0	0
Detroit, Mich	6	12	18	0	0	0
Buffalo, N. Y	13	20	33	1	0	1
Green River:						
Dutch John, Utah	0	32	32	0	3	3
Hudson River:						
Poughkeepsie, N. Y	4	12	16	0	0	0
Illinois River:						
Peoria, Ill	13	30	43	0	1	1
Grafton, Ill	4	27	31	1	2	3
Kanawha River: Winfield Dam, W. Va	0	5	5	0	0	0
Kansas River:						
De Soto, Kans	39	35	74	5	3	8
Klamath River:						
Keno, Ore	4	18	22	0	0	0
Little Miami River:						
Cincinnati, Ohio	6	14	20	0	0	0
Maumee River:						
Toledo, Ohio	4	24	28	1	2	3
Merrimack River:						
Lowell, Mass	3	12	15	0	0	0
Mississippi River:						
St. Paul, Minn	10	53	63	0	3	3
Dubuque, Iowa	13	24	37	0	0	0
Burlington, Iowa	19	27	46	1	1	2
E. St. Louis, Ill	37	23	60	3	1	4
Cape Girardeau, Mo	61	28	89	9	1	10
W. Memphis, Ark	28	22	50	4	1	5
Vicksburg, Miss	40	27	67	2	0	2
Delta, La	62	19	81	4	1	5
New Roads, La	29	19	48	2	<1	2
New Orleans, La	45	22	67	7	3	10
Missouri River:						
Williston, N. Dak	14	31	45	2	4	6
Bismarck, N. Dak	4	37	41	0	2	2
Yankton, S. Dak	7	39	46	0	5	5
Omaha, Nebr	73	27	100	9	5	14
St. Joseph, Mo	190	38	228	37	4	41
Kansas City, Kans	215	46	261	19	2	21
Missouri City, Mo	97	28	125	19	3	22
St. Louis, Mo	117	30	147	17	4	21
Monongahela River:						
Pittsburgh, Pa	1	5	6	0	0	0
North Platte River:						
Henry, Nebr	38	40	78	2	19	21
Ohio River:						
Toronto, Ohio	7	11	18	0	0	0
Addison, Ohio	2	12	14	0	0	0
Huntington, W. Va	4	9	13	1	0	1
Cincinnati, Ohio	4	10	14	0	0	0
Louisville, Ky	3	10	13	0	1	1
Evansville, Ind	11	8	19	1	0	1
Cairo, Ill	15	18	33	2	0	2
Ouachita River:						
Bastrop, La	13	33	46	1	0	1
Pend Oreille River:						
Albeni Falls Dam, Idaho	3	7	10	0	1	1
Platte River:						
Plattsmouth, Nebr	277	49	326	40	5	45
Potomac River:						
Williamsport, Md	2	11	13	0	0	0
Great Falls, Md	3	9	12	0	0	0
Washington, D.C	2	9	11	<1	0	<1
Rainy River:						
Baudette, Minn	9	46	55	0	0	0
International Falls, Minn	7	29	36	0	0	0
Raritan River:						
Perth Amboy, N. J. (5 ft. Below Surface)	3	10	13	0	3	3
Perth Amboy, N. J. (5 ft. Above Bottom)	1	14	15	0	3	3
Red River, North:						
Grand Forks, N. Dak	20	71	91	3	5	8
Red River, South:						
Denison, Tex	1	54	55	0	8	8
Index, Ark	46	35	81	6	1	7
Bossier City, La	24	29	53	2	0	2
Alexandria, La	61	25	86	14	0	14
Rio Grande River:						
Alamosa, Colo	5	27	32	0	2	2
El Paso, Tex	3	24	27	<1	8	8
Laredo, Tex	145	32	177	11	1	12
Brownsville, Tex	25	20	45	3	4	7
Roanoke River:						
John H. Kerr Resr/Dam, Va	5	11	16	1	0	1
Sabine River:						
Ruliff, Tex	11	25	36	1	0	1
Sacramento River:						
Greens Landing, Calif	0	5	5	0	0	0
St. Lawrence River:						
Massena, N. Y	2	15	17	0	0	0
San Joaquin River:						
Vernalis, Calif	5	14	19	1	6	7
San Juan River:						
Shiprock, N. Mex	10	20	30	1	3	4
Savannah River:						
North Augusta, S. C	19	15	34	1	0	1
Port Wentworth, Ga	18	18	36	<1	0	<1
Schuylkill River:						
Philadelphia, Pa	5	5	10	1	0	1
Shenandoah River:						
Berryville, Va	5	9	14	0	0	0
Ship Creek:						
Anchorage, Alaska	1	7	8	0	0	0
Snake River:						
Ice Harbor Dam, Wash	0	10	10	0	0	0
Wawawai, Wash	10	8	18	0	0	0
Payette, Idaho			No	Report		
South Platte River:						
Julesburg, Colo	9	58	67	1	36	37
Spokane River:						
Post Falls Dam, Idaho	1	4	5	0	0	0
Susquehanna River:						
Sayre, Pa	2	5	7	0	0	0
Conowingo, Md	4	11	15	0	0	0
Tennessee River:						
Lenoir City, Tenn	1	7	8	0	0	0
Chattanooga, Tenn	6	15	21	<1	0	<1
Bridgeport, Ala	2	13	15	0	0	0
Pickwick Landing, Tenn	5	16	21	0	0	0
Tombigbee River:						
Columbus, Miss	7	9	16	1	0	1
Truckee River:						
Farad, Calif	2	7	9	0	0	0
Verdigris River:						
Nowata, Okla	21	35	56	1	1	2
Wabash River:						
New Harmony, Ind	28	21	49	2	1	3
Willamette River:						
Portland, Ore	2	3	5	0	0	0
Yakima River:						
Richland, Wash	1	9	10	0	3	3
Yellowstone River:						
Sidney, Mont	293	17	310	61	3	64
Maximum	428	1,183	1,611	61	36	64
Minimum	0	3	5	0	0	0

Note: These data are preliminary; reanalysis of some samples may be made and additional analysis not completed at the time of the report may become available. For final data, one should consult the network's Annual Compilation of Data (7).


WASHINGTON
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NEW YORK
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KANSAS
MISSOURI
CALIFORNIA
ARIZONA
NEW MEXICO
OKLAHOMA
ARKANSAS
TENN.
N. CARO.
S. CARO.
GEORGIA
ALABAMA
MISS.
TEXAS
FLORIDA

FIGURE 1.—TOTAL BETA ACTIVITY (pc/liter) IN SURFACE WATERS, MAY 1964

and the suspended solids (on the charred membrane filter) in an internal proportional counter. Reference sources of U_3O_8, which give a known count rate if the instrument is in proper calibration, are used for daily checking of the counters.

Results

Table 1 presents May 1964 results of alpha and beta analyses of U. S. surface waters. The stations on a river are arranged in the table according to their relative location on the river, the first station listed being closest to the headwaters. These data are preliminary. Replicate analyses of some samples as well as some analyses incomplete at the time of this report will be included in the system's "Annual Compilation of Data" (*7*). The figures for gross alpha and gross beta radioactivity represent either determinations on composite samples or means of weekly determinations where composites were not made. The monthly means are reported to the nearest pc/liter. When all samples have zero pc/liter, the mean is reported as zero; when the calculated mean is between zero and 0.5 the mean is reported as <1 pc/liter.

In order to obtain a geographical perspective of the radioactivity in surface waters, the numbers alongside the various stations in figure 1 give the May 1964 average total beta activity in suspended-plus-dissolved solids in raw water collected at that station. Results for the years 1957–1962 have been summarized by Weaver *et al.* (*9*).

Strontium–90 Determinations

Beginning in 1959, strontium–90 analyses of the total solids of surface waters were made quarterly on three-month composites of aliquots from weekly samples. Beginning in November 1962, the frequency of analysis was reduced to two quarterly samples per year at each sampling point except those stations immediately below nuclear installations, where quarterly analyses were continued. Floyd and Weaver summarized the strontium–90 results obtained from 1959 through 1963 in the August 1964 issue of *RHD* (*10*). The most recent strontium–90 results appeared in the October 1964 issue of *RHD* (*11*).

Discussion

The monthly dissolved beta activity averages exceeded 100 pc/liter only on the Columbia River. Of the six stations on the Columbia River, the four downstream from the Hanford Atomic Products Operations facility had averages of between 103 and 1,183 pc/liter.

The maximum monthly average dissolved alpha activity observed at all of the stations was 36 pc/liter. This activity is associated with dissolved natural surface minerals. Of all stations, four on different rivers had monthly average dissolved alpha activity greater than 10 pc/liter.

While there are no generally applicable standards for surface waters, the radioactivity associated with dissolved solids provides a rough indication of the levels which could occur in treated water, since nearly all suspended matter is removed by the treatment process (*12*). The Public Health Service Drinking Water Standards state that in the absence of strontium–90 and alpha emitters,[1] a water supply is acceptable when the gross beta concentration does not exceed 1,000 pc/liter (*13*).

REFERENCES

(*1*) Division of Water Supply and Pollution Control, Public Health Service: *National Water Quality Network Annual Compilation of Data, PHS Publication No. 663, 1958 Edition*, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Price $1.50.

(*2*) *Ibid.*, 1959 Edition. Price $1.75.

(*3*) *Ibid.*, 1960 Edition.[2]

(*4*) *Ibid.*, 1961 Edition.[2]

(*5*) *Ibid.*, 1962 Edition.[2]

(*6*) *Ibid.*, 1963 Edition (in press).

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(*8*) American Public Health Association, American Water Works Association and Water Pollution Control Federation: *Standard Methods for the Examination of Water and Wastewater*, 11th Edition, New York (1960).

(*9*) Weaver, L., A. W. Hoadley, and S. Baker: Radioactivity in Surface Waters of the United States, 1957-1962, *Radiological Health Data, 4:* 306-16 (June 1963).

(*10*) Floyd, E. P. and L. Weaver: Trends of Strontium-90 Levels in Surface Waters of the United States, 1959-1963, *Radiological Health Data 5:* 390-94 (August 1964).

(*11*) Division of Water Supply and Pollution Control, Public Health Service: Strontium-90 and Gross Radioactivity in Surface of the United States, April 1964, *Radiological Health Data 5:* 493-98 (October 1964).

(*12*) Straub, C. P.: Significance of Radioactivity Data, *Journal of the American Water Works Association 53:* 704 (June 1961).

(*13*) Public Health Service: *Drinking Water Standards, Revised 1962, Public Health Service Publication No. 956*, Superintendent of Documents, Government Printing Office, Washington, D.C. 20402 (March 1963), price 30 cents.

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[1] Absence is taken here to mean a negligibly small fraction of the specific limits of 3 pc/liter and 10 pc/liter for unidentified alpha emitters and strontium-90, respectively.

[2] Single free copies of this publication may be obtained from: Public Inquiries Branch, Public Health Service, U.S. Department of Health, Education, and Welfare, Washington, D.C. 20201.

RADIOACTIVITY IN WATERS AND SEDIMENTS OF THE COLORADO RIVER BASIN, 1950–1963

D. T. Wruble, S. D. Shearer, D. E. Rushing, and C. E. Sponagle[1]

Part I. Historical Background

Collection and analysis of water and sediment samples from the Colorado River Basin for their radioactivity content have been carried out by the Public Health Service since 1950. The resulting data have made it possible to determine with a high degree of accuracy the influence of extensive uranium mining and milling operations upon the waters of the Basin. Uranium extraction operations have been conducted in the Basin since the early 1940's.

The purpose of this paper is to present a brief summary of the radioactivity found in surface water and sediment samples collected to date, and to present some conclusions regarding differentiation between natural radioactivity and radioactivity due to uranium mining and milling activities. Part I of the paper presents a historical summary of data collected before the beginning of the Colorado River Basin Water Quality Control Project. Parts II and III present a detailed summary of the radioactivity in surface water and sediment at specific locations throughout the Colorado River Basin as reported by the above-mentioned Project.

Uranium-bearing ore, as it is delivered to the mill for processing may have a uranium content of 0.1 to 2 percent as U_3O_8, and generally averages about 0.25 percent (*1*). This uranium is present as uranium–238 and uranium–235, both of which are naturally-occurring parents of long chains of radioactive daughter products. The decay chain of uranium–238, known as the uranium series of elements, contains eight alpha-emitters and six beta-emitters and is of primary concern. Although the milling processes are designed to extract uranium from the ore, some small portion (1 to 10 percent) of the total uranium, along with various uranium daughters and extraneous material present in the ore, remains in the waste liquors and spent ore solids (*1*). These radionuclides represent a wide range of relative hazard. Radium–226, one member of the uranium series, is the most hazardous, with an $(MPC)_w$ of 3.3 pc/liter for the population at large (*2*). The additional fact that essentially the entire amount of the radium–226 present in the ore, which by any measure is very large relative to what are considered safe concentrations, will be contained in the mill wastes, provides the basis for directing major waste control efforts towards this radionuclide (*1*). It is generally true that effective control of radium–226 pollution from uranium mill process wastes precludes any dangerous contamination of receiving waters by other members of the uranium series (*1*).

In October 1950, eight river water samples in the vicinity of four operating uranium mills were collected by the Public Health Service and analyzed for dissolved radium-226 (*3*). The results are shown in table 1. These limited data indicated the influence of waste discharges from these operating mills upon the river water.

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TABLE 1.—DISSOLVED RADIUM-226 IN RIVER WATER SAMPLES COLLECTED UPSTREAM AND DOWNSTREAM FROM OPERATING URANIUM MILLS IN 1950

River	Dissolved radium-226 (pg/liter) [a]	
	Above mill	Below mill
Animas, Mill A	0.20	4.5
Colorado, Mill B	0.36	4.5
San Miguel, Mill D	0.13	16.9
San Miguel, Mill E	0.15	43.4

[a] pc is taken as equivalent to pg.

In September 1955, at the request of several State Departments of Health, the Public Health Service conducted a brief reconnaissance survey of the surface water contamination arising from uranium milling operations in the Colorado Plateau area (*4*). This survey was designed to indicate the extent of the situation and possible future waste control programs by the various Basin States. Single instantaneous samples of water, bottom sediments, and aquatic organisms (when present) were collected from streams in the vicinity of seven of the eight uranium mills then operating. The data for water and sediment are summarized in table 2.

The data from the 1955 survey indicated that the radioactivity in the waste discharges from uranium mills in the Colorado Plateau area varied widely. It was determined as a result of this survey that further investigation of the effects of waste discharges was desirable.

Accordingly, during 1956 a five-day survey was carried out (*5*) in the vicinity of the two mills exhibiting the greatest effects upon stream water and sediment. During this period representative sampling of water, sediment, and biological media was carried out. The data obtained on water and sediments immediately upstream and at several downstream locations are summarized in table 3.

TABLE 3.—GROSS ALPHA RADIOACTIVITY AND RADIUM-226 IN RIVER WATER AND SEDIMENTS NEAR URANIUM MILLS, 1956

Location, San Miguel River	Water [a]		Sediments	
	Gross dissolved alpha (pc/liter)	Soluble radium-226 (pg/liter)	Gross alpha (pc/gram)[b]	Radium-226 (pg/gram)[b]
Mill D: Immediately upstream	9	0.2	20	1.2
4.4 miles downstream	480	22	9,900	2,100
8.9 miles downstream	200	7.2	45	7.8
15.4 miles downstream	200	5.3	95	22.8
Mill E: Immediately upstream	—	—	10	0.7
2.3 miles downstream	180	76	1,950	730
4.9 miles downstream	100	53	1,200	200
11.2 miles downstream	90	88	310	92
20.8 miles downstream	80	65	430	114
29.4 miles downstream	130	50	75	16.8
38.1 miles downstream	50	32	100	24

[a] Average of 5 daily composites.
[b] pc and pg/gram ash weight.

TABLE 2.—GROSS ALPHA RADIOACTIVITY AND RADIUM-226 IN RIVER WATER AND SEDIMENT NEAR URANIUM MILLS, 1955

River and mill		Water				Sediment	
		Gross dissolved alpha (pc/liter)		Dissolved radium-226 (pg/liter)		Gross alpha (pc/gram)	
		Above mill	Below mill	Above mill	Below mill	Above mill	Below mill
Animas	A	≈0	27	0.2	3.3	16	850
Colorado	B	≈0	41	0.4	0.4	15	45
Colorado	C	3	140	0.3	39	—	[a] (5,600)
San Miguel	D	8	124	0.3	9.4	17	[a] 1,800 (6,600)
San Miguel	E	—	2,160	—	86	—	2,400
South Creek	F	31	28,500	0.3	81	—	3,200
San Juan	G	10	0	0.2	0.3	13	10

[a] Number in parentheses refers to activity at uranium mill outfall.

The data from table 3 show a quite definite increase of dissolved radium-226 in the river immediately below each mill with a gradual decrease from maximum concentrations downstream from each mill. It is interesting to note the levels of radioactivity in bottom sediments proceeding downstream from each mill. In the case of mill "D" there is a rapid decrease resulting from occurrence of a flash flood about a month prior to sample collection. Below mill "E" the decrease was more gradual due to thicker and more extensive sediment deposits that were less susceptible to the scouring action of high flows.

These earlier data indicated clearly that a real water pollution problem was occurring, specifically that dissolved radium-226 concentrations were considerably above allowable levels in some cases. The 1962 Public Health Service Drinking Water Standards set the limit for radium-226 at 3 pg/liter for public water supplies (*6*). As a result, during the summer of 1958 and fall of 1959, extensive surveys of radioactive pollution of the Animas River (Colorado-New Mexico) were carried out. This was done under provisions of the Federal Water Pollution Control Act on the basis of a request by the State of New Mexico. Since details of these surveys are too numerous for presentation here, the reader is referred to the referenced reports (*7,8*). Information gained from these studies showed the levels which can result from radioactive pollution of the water environment and the various pathways through which such contamination may move. As a result of this work, the responsible mill on the Animas River promptly took measures to abate pollution with very satisfactory results.

Immediately following the Animas River studies, the Colorado River Basin Water Quality Control Project was organized with radioactivity studies being a major part of its early activities.

Part II

Based on the accumulated data on radioactive contamination of Colorado River Basin surface waters and river sediments, a conference on uranium milling wastes was held in October 1957 at Cortez, Colorado, attended by representatives of the States of Arizona, New Mexico, Colorado, and Utah and the U. S. Public Health Service. At this conference, a Radium Monitoring Network was suggested to provide needed continuous data on radioactivity contributed by uranium mining and milling operations to Colorado River Basin surface waters. The envisioned purpose of this network was to define both natural and industrial sources of radioactive pollution, and to measure either improvement or degradation of surface waters due to these contamination sources. Accordingly, a Radium Monitoring Network was established when the U.S. Public Health Service's Colorado River Basin Water Quality Control Project was organized in 1960 under provisions of the Federal Water Pollution Control Act. The network has since been expanded to 27 stations (figure 1), seven of which are automatic stations and the remainder grab sampling stations.

Depending upon the type of data required and physical location limitations encountered at each station, grab samples are collected one to six times weekly and automatic samplers collect a 21-ml sample every hour. At the Colorado River Basin Project Laboratory, the samples are composited into weekly or monthly composite samples, filtered through a 0.45 micron pore size membrane filter, and the filtrate analyzed for the desired radionuclides.

Radium-226, with the lowest $(MPC)_w$ of all radio nuclides (*9*) has been the radioactive contaminant of greatest concern in uranium mill discharges (*1*). Consequently initial and primary emphasis was placed on analysis of network samples for radium-226 only. In October 1963, uranium determinations were

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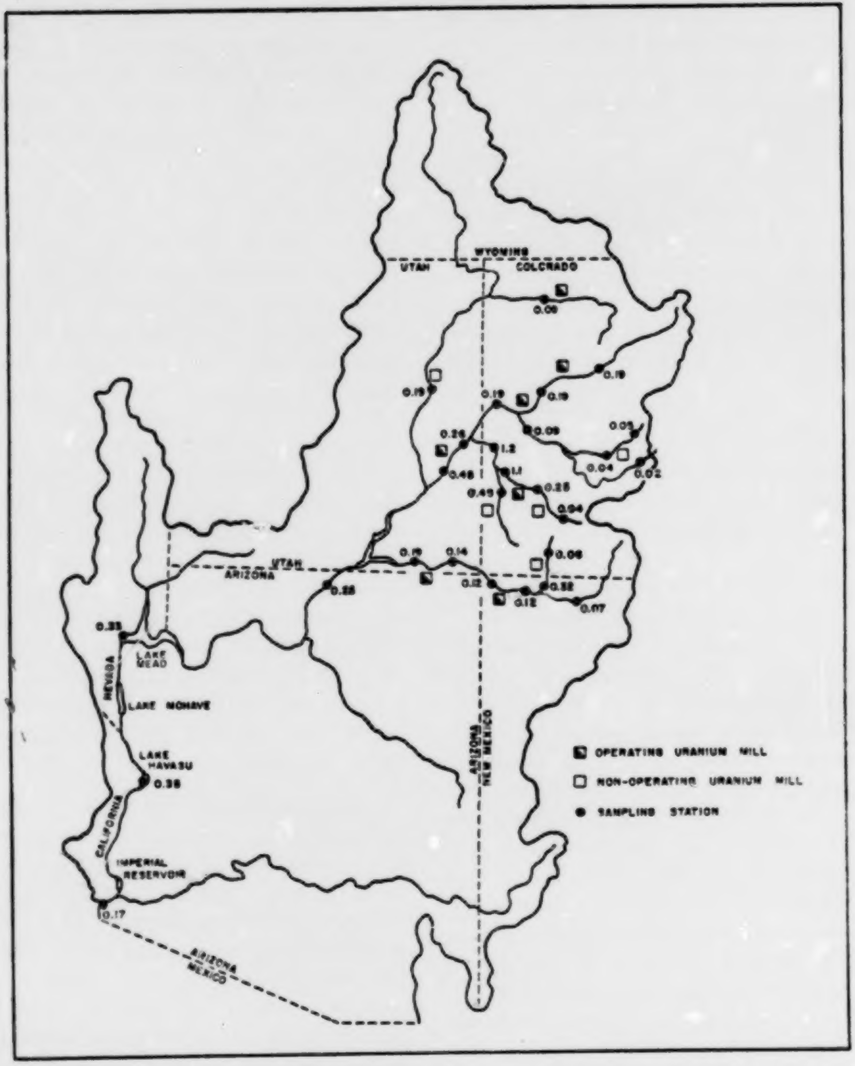
WYOMING
UTAH
COLORADO
0.09
0.19
0.19
0.19
0.19
0.26
1.2
0.46
1.1
0.05
0.09
0.04
0.02
0.49
0.25
0.04
0.06
0.19
0.14
UTAH
ARIZONA
0.22
0.12
0.32
0.12
0.07
0.33
LAKE MEAD
NEVADA
LAKE MOHAVE
LAKE HAVASU
0.36
CALIFORNIA
IMPERIAL RESERVOIR
0.17
ARIZONA
MEXICO
ARIZONA
NEW MEXICO
OPERATING URANIUM MILL
NON-OPERATING URANIUM MILL
SAMPLING STATION

FIGURE 1.—AVERAGE RADIUM-226 (pg/liter) IN SURFACE WATERS OF THE COLORADO RIVER BASIN, (JAN. 61–DEC. 63)

added and present samples are being gamma scanned and analyzed for lead-210, polonium-210, thorium, gross beta activity, and gross alpha activity in suspended solids. These determinations have been added to provide a more definitive picture of the total radioactivity in Basin waters resulting from uranium industry operations. Since only preliminary results have been obtained to date on these more recent determinations, these data are not presented in this report.

A sumary of radium-226 and uranium results obtained from the various Radium Monitoring Network stations over the reporting period (January 1961 through December 1963) is presented in table 4, and a summary of all samples collected is given in table 5. Background sampling stations listed are defined as those upstream from uranium mining and milling operations or other contamination sources such as the radium-bearing mineral springs near Glenwood Springs, Colorado.

TABLE 4.—RADIUM-226 AND URANIUM IN COLORADO RIVER BASIN SURFACE WATERS AT RADIUM MONITORING NETWORK STATIONS, JANUARY 1961–DECEMBER 1963.

Stations	Radium-226 (pg/liter)		Uranium (μg/liter)	
	Average	Median	Average	Median
Background Stations [a]				
Animas River: Durango, Colo	0.06	0.06	1.2	1.1
Gunnison River: above Gunnison, Colo	0.05	0.04	1.1	1.0
below Gunnison, Colo	0.04	0.04	1.9	1.6
San Juan River: above Farmington, N. M	0.07	0.06	3.2	3.3
San Miguel River: above Naturita, Colo	0.04	0.04	1.3	1.3
Tomichi Creek: above Gunnison, Colo	0.02	0.02	—	—
Non-background Stations				
Animas River: Colo. N.M. State Line	0.32	0.25	4.4	2.6
Colorado River: DeBeque, Colo	0.19	0.17	3.6	4.2
Fruita, Colo	0.19	0.18	9.7	9.7
Lake Havasu	0.35	0.36	8.4	8.2
Lake Mead	0.33	0.32	7.9	7.9
above Moab, Utah	0.26	0.26	10	10
below Moab, Utah	0.45	0.31	12	12
Page, Ariz	0.25	0.25	9.1	8.6
Silt, Colo	0.19	0.18	2.9	3.1
Yuma, Ariz	0.17	0.16	8.4	8.3
Dolores River: Bedrock, Colo	0.48	0.49	14	11
Gateway, Colo	1.2	0.96	9.3	9.2
Green River: Green River, Utah	0.09	0.09	5.4	5.7
Gunnison River: Grand Junction, Colo	0.09	0.08	11	12
San Juan River: below Farmington, N. M	0.12	0.12	4.6	3.6
above Mexican Hat, Utah	0.14	0.14	8.4	8.1
below Mexican Hat, Utah	0.19	0.14	9.2	9.1
below Shiprock, N. M	0.12	0.11	15	15
San Miguel River: above Uravan, Colo	0.25	0.24	7.8	5.8
below Uravan, Colo	1.1	0.99	26	24
Yampa River: Maybell, Colo	0.09	0.09	2.8	2.4

[a] Background stations are those upstream from uranium mining and milling operations or other contamination sources.

In keeping with the philosophy of minimum exposure (*9*), the majority of the uranium processing mills in the Colorado River Basin have successfully maintained negligible radioactivity contributions to Colorado River Basin waters through their efforts to provide proper treatment and containment of milling waste products. Even at those mills where significant contributions have occurred since 1960, only 6 of the 930 individual composite samples analyzed for radium–226 have indicated concentrations above the currently accepted yearly average limit of 3 pg/liter for radium in drinking water (*6*). No network sampling station has exhibited an overall average above this limit and only two stations have sustained average radium–226 concentrations slightly above the 1 pg/liter suggested maximum desirable level for Colorado River Basin waters (*10*).

The effect of various uranium milling operations on radium–226 concentrations in surface waters is portrayed in figure 1 in the varying average concentrations shown at nonbackground stations throughout the Upper Basin. Once the various Upper Basin contamination sources have exerted their influence, the Lower Basin reservoirs exhibit an apparently stabilized average concentration of approximately 0.34 pg/liter. Some as yet undetermined factors reduce this to 0.17 pg/liter at Yuma, Arizona. The Radium Monitoring Network data indicate that radium–226 concentrations below 0.10 pg/liter in Colorado River Basin streams can be considered background levels, while concentrations above this level are indicative of contamination sources somewhere upstream.

TABLE 5.—SUMMARY OF RESULTS OF RADIUM-226 AND URANIUM IN COLORADO RIVER BASIN SURFACE WATERS, JANUARY 1961–DECEMBER 1963

Type of station	Radium-226			Uranium		
	Number of samples	Average concentration (pg/liter)	Range (pg/liter)	Number of samples	Average concentration (μg/liter)	Range (μg/liter)
Background stations	116	0.05	0.01–0.16	64	1.6	0.0–8.3
Non-background stations	814	0.41	0.01–7.2	544	11	0.0–150
All stations	930	0.37	0.00–7.6	608	10	0.0–150

A specific example of radium-226 contamination of river water by uranium milling operations is shown in figure 2. The graph illustrates the effect on the river of past operations through the continuing erosion into the river of residual tailings at a nonoperating uranium mill. The more pronounced effect of an operating mill discharging wastes to the river is evident in the higher concentrations recorded below the second mill.

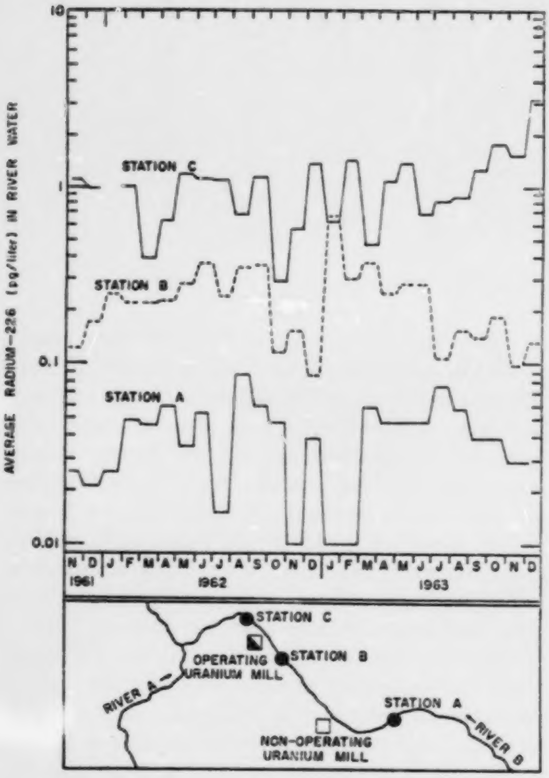

FIGURE 2.—EXAMPLE OF URANIUM MILL EFFECTS ON RADIUM-226 CONCENTRATIONS IN RIVER WATER

As portrayed in figure 2, once a uranium mill discontinues discharging waste products to a river, the radioactivity concentrations below the closed mill do not return to background levels immediately. Even if residual tailings do not reach the river, the assimilation of uranium milling wastes by stream sediments during mill operation can play an important part in the concentrations found in river water after contamination practices have ceased. It has been shown by both laboratory experiment and field studies that dissolved radium-226 levels in stream waters can depend to a large degree on the amount of radium-226 contained in the stream bed sediments, and that various hydraulic, physical and chemical factors govern the rate of release of the radium-226 to the overlying waters (*11*).

Preliminary data on radium-226 concentrations in river water coupled with bottom sediment records (see Part III) below uranium mills that have discontinued all waste releases to a river indicate that the rate of removal of radioactive sediment contaminants from a specific stream location is fairly slow. In one instance, a generalized slope drawn through plotted monthly averages of radium-226 concentration levels recorded in river water over a period of time show a drop from approximately 0.36 pg/liter in July 1961 to 0.16 pg/liter in December 1963. If this reduction continues at the same general rate, it will require a minimum of four years for concentrations at this particular station to return to background levels. One would expect the reduction rate to decrease as time passed, thereby requiring more than the estimated four years to attain background concentrations.

It should be emphasized that the sediment contaminant removal action referred to here pertains to only one specific location on the stream. Although radiation levels may be reduced at a given location over a period of time, the sediment contaminants originally producing the higher concentrations are continually being moved downstream to exert their cumulative influence at another location. This will more than likely be a reservoir or similar catch basin where the radioactivity-carrying sediments will ultimately accumulate (*11*).

It is obvious from the above discussion that knowledge of radium-226 concentration levels in river water at a given location in the Colorado River Basin can provide an excellent indication of intensities of radioactive contamination by uranium mining and milling operations. In addition, uranium concentrations in river water can also portray uranium mining or milling process contamination, but do not indicate degrees of contamination as reliably as does radium-226. This is to be expected, since uranium is the material being recovered in the milling processes while radium–226 is always a waste product. Additionally, the effects of natural concentrations of uranium in stream bed deposits tend to vary widely with geographic location.

The rather high solubility of uranium and its readiness to form soluble complex ions (*12*) results in much higher leaching rates of uranium than of radium–226 from natural stream bed and watershed deposits. This is quite evident when the average uranium and radium–226 concentrations at background stations listed in table 4 are compared. The background station radium–226 activities average 4.9 percent of the uranium activities listed when compared on a curie basis. This means there are approximately 3×10^7 grams of uranium present in background waters for every gram of radium–226.[1]

This high solubility and subsequent concentration variations in water at different geographic locations makes it difficult to establish an average uranium concentration that can be designated as being typically background. Using the same stations classified in table 4 as background radium–226 concentrations, uranium levels below approximately 4 μg/liter would indicate background concentrations in the upper reaches of Colorado River Basin streams. Stations further downstream, however, show much higher concentrations which seemingly can be considered background. The Green River station at Green River, Utah, and the Gunnison River station at Grand Junction, Colorado, are both essentially background stations since they are downstream from uranium mills which release no significant contaminants to the streams. The radium–226 levels at these stations are at background, but the uranium levels of 5.4 and 11 μg/liter correspond to those found at other stations showing uranium mill contamination with radium–226 levels of three and four times background.

Uranium milling effects on uranium levels in Colorado River Basin waters are evident in table 4. The average level for nonbackground stations for the reporting period show 11 μg/liter as compared to the 1.6 μg/liter at the arbitrary background stations. The Lower Basin reservoirs exhibit an apparently stabilized concentration (similar to that observed for radium–226) near 8 μg/liter. The noted reduction in radium–226 concentrations at Yuma, Arizona, however, is not evident in the uranium concentrations. No Radium Monitoring Network sample has produced a uranium concentration above the suggested limit of 29,500 μg/liter.

Referring once again to the relationship between radium–226 and uranium concentrations in river water, table 6 is presented to show radium-uranium ratios (on a curie basis) found in Colorado River Basin waters. It seems noteworthy that the range of ratios is relatively narrow. This relationship can be utilized in obtaining a good idea of radium–226 concentrations, for instance, by determining the uranium concentration, or vice versa. From the knowledge of only one factor, additional relationships between radium in water and radium and gross alpha in sediment can be determined. These relationships are discussed in Part III.

TABLE 6.—RADIUM-226-URANIUM RATIOS IN COLORADO RIVER BASIN SURFACE WATERS, JANUARY 1961–DECEMBER 1963 [a]

Value	Background stations	Non-background stations	All stations
Average	0.049	0.047	0.048
Range	0.031–0.071	[b] 0.012–0.106	[b] 0.012–0.106

[a] The ratio is computed on a curie rather than on a weight basis.

[b] This range disregards an 0.190 ratio at Gateway, Colorado. If this higher figure is used, the average changes to 0.054 for non-background stations and 0.053 for all stations.

Part III. Basinwide Sediment Network

While radioactivity concentrations in water indicate immediate levels of contamination, algae, fish and other aquatic life are available as indicators of long term contamination levels in water. For ease of collection, sample preparation and analysis, stream and reservoir sediments have been shown to be the most desirable indicator medium.

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[1] Uranium specific activity of 1.475×10^6 grams per curie was used here for computation purposes.

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Therefore, when the Colorado River Basin Project was established, one of the first study programs initiated was the Basinwide Sediment Network. The objectives of this program have been to determine:

(a) the radioactivity levels in Basin River sediments;
(b) distribution of this radioactivity throughout the Basin;
(c) background levels versus levels below uranium mining and milling operations;
(d) effects of river hydrology on sediment deposition and transport.

For the first three sampling surveys (August 1960, March 1961, August 1961) the Basinwide Sediment Network consisted of 88 sampling stations. Examination of the data after the third survey indicated that the number of stations could be reduced without reducing the effectiveness of the program. Subsequently, the last four surveys (March 1962, September–December 1962, August 1963, March 1964) have been conducted using the present 30-station network.

Frequency and dates of sampling surveys have been designed to provide data on the effects of periodic flow changes. Colorado River Basin streams are typically unregulated, particularly in the Upper Basin, and most of the total annual flow occurs during late spring. The fall and winter low flow periods permit buildup of stream bed sediment deposits which are then effectively flushed downstream during spring and summer high flows. Sediment sampling dates, therefore, are scheduled in March, just before high flows carry the year's deposition downstream, and again in summer or fall after the flushing action has been completed.

Network samples are analyzed at the Colorado River Basin Project Laboratory for radium–226 and gross alpha activity. A summary of the analytical results is presented in table 7. These results suggest that hydrologic factors play their part in the low flow period buildup of contaminated sediments and the subsequent high flow channel scouring and sediment mixing. Radium–226 concentrations in the Upper Basin river sediments average higher in spring after the sediment buildup than the corresponding fall concentrations after the high spring and summer flows have removed a portion of the earlier deposition and mixed in a new load of uncontaminated sediments. Limited figures are available for gross alpha; however, these data also indicate the higher springtime concentrations.

The seasonal variations indicated by the Lower Basin river and reservoir sampling stations are not considered significant at this point, due to the relatively few samples collected. As more data are obtained, it is anticipated that the results will indicate essentially the same concentration levels the year round, resulting from the settling of sediments in the reservoirs and the subsequent stabilizing effect similar to that noted in Lower Basin water radioactivity.

Comparison of radium–226 concentrations found in pool sediments to those found in riffle sediments shows that while some of the pool sediments contained more radium than did riffle sediment, the data are generally not significantly different at a given location. In some cases, the riffle sediment contained more radium than the pool sediment (*11*). This leads to the conclusion that stream turbulance does not significantly affect sediment concentration levels at any specific location except in its role of moving sediments downstream.

Further examination of Basinwide Sediment Network data in table 7 provides several other observations regarding the distribution of radioactive sediments in the Colorado River Basin. Upper Basin background levels for radium–226 (above uranium mining and milling operations or other contamination sources) average 1.1 pg/gram of sediment while the overall average of non background stations in the Upper Basin is 2.3 pg/gram, showing the effect of the contamination sources. The Lower Basin reservoirs then exhibit their settling and collecting basin action, even with the relatively limited data available. Lake Mead sediments average 2.9 pg/gram (from 1960 and 1961 surveys), Lake Mohave averages 1.3 pg/gram,

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TABLE 7.—RADIUM-226 AND GROSS ALPHA RADIOACTIVITY IN COLORADO RIVER BASIN SEDIMENTS, AUGUST 1960–MARCH 1964

Type of station and time period	Radium-226 (pg/gram)				Gross alpha (pc/gram)			
	No. of samples	Average	Median	Range	No. of samples	Average	Median	Range
Background stations								
Fall	43	1.1	1.1	0.3-1.8	24	8	8	4-14
Spring	14	1.3	1.2	0.6-1.6	4	9	9	5-14
Overall	57	1.1	1.1	0.3-1.8	28	8	8	4-14
Non-background station—upper basin								
Fall	143	2.1	1.5	0.5-14	103	15	11	2-100
Spring	77	2.7	1.5	0.4-14	33	22	12	5-140
Overall	220	2.3	1.5	0.4-14	136	16	11	2-140
Non-background stations—lower basin (river stations)								
Fall	13	0.7	0.8	0.3-1.3	9	4	4	3-20
Spring	5	0.6	0.4	0.4-0.9	3	5	—	3-9
Overall	18	0.7	0.6	0.3-1.3	12	4	4	2-20
Lake Mead [a]								
Overall	38	2.9	—	0.5-5.5	21	16	—	7-32
Lake Mohave								
Fall	7	1.2	1.2	0.6-2.0	5	5	—	3-13
Spring	3	1.5	—	0.9-2.3	1	10	—	—
Overall	10	1.3	1.3	0.6-2.3	6	6	—	3-13
Lake Havasu								
Fall	9	2.3	2.2	1.5-3.3	6	18	—	12-24
Spring	4	2.0	—	1.8-2.3	1	16	—	—
Overall	13	2.2	2.1	1.5-3.3	7	18	—	12-24
Imperial Reservoir								
Fall	9	0.8	0.8	0.3-1.1	6	5	—	2-10
Spring	4	0.5	—	0.4-0.8	1	2	—	—
Overall	12	0.8	0.8	0.3-1.1	7	5	—	2-10

[a] From 1960–1961 Surveys (*13*) only.

and Lake Havasu averages 2.2 pg/gram. Imperial Reservoir at the lower end of the Colorado River exhibits background levels with 0.8 pg/gram. It is apparent from its higher concentrations that Lake Mead, being the first upstream reservoir, has been the primary collecting place for contaminated sediments. Now that Glen Canyon Dam has been completed, Lake Powell will take its place and become the primary final resting place for contaminated sediments.

The Lower Basin river stations indicate an overall average radium–226 concentration of 0.6 pg/gram of sediment, which is less than the observed background levels in the Upper Basin. It is apparent then that the lower Basin reservoirs collect practically all of the radioactive sediments carried down the Colorado River.

Gross alpha results indicate essentially the same radioactive sediment distribution pattern. Upper Basin background levels average 8 pc/gram of sediment and non-background stations produce a 16 pc/gram average. Lake Mead results from 1960 and 1961 surveys indicated a 16 pc/gram average, Lake Mohave indicated 6 pc/gram, Lake Havasu indicated 18 pc/gram, Imperial Reservoir indicated 5 pc/gram, and the Lower Basin river stations indicated 4 pc/gram. A disparity appears in both radium–226 and gross alpha results, wherein Lake Havasu averages are higher than those for Lake Mohave. Since Lake Mohave is further upstream, the opposite should be true. A possible explanation for this might be the presence of natural uranium deposits in some streams or dry washes in the immediate vicinity of Lake Havasu from which radioactive sediments could be obtained. However, this theory has not been substantiated.

Although the radium–226 and gross alpha results indicate generally the same distribution pattern of radioactive sediments, the concentration ratios between these factors do not remain proportional as one proceeds downstream. This is demonstrated in table 8.

Again, the Lake Havasu ratio is out of proportion to the pattern followed through the rest of the Basin. Ignoring this figure, however, the ratios show a systematic increase as one proceeds downstream, with the usual stabilization noted at Imperial Reservoir and the Lower Basin river stations.

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TABLE 8.—RATIOS OF RADIUM-226 TO GROSS ALPHA IN COLORADO RIVER BASIN SEDIMENTS, AUGUST 1960–MARCH 1964

Station	Radium-226 pg/gram	Gross Alpha pc/gram	Ratio: radium-226/alpha
Upper Basin background stations	1.1	8	0.14
Upper Basin non-background stations	2.3	16	0.14
Lake Mead	2.9	16	0.18
Lake Havasu	2.2	18	0.12
Lake Mohave	1.3	6	0.22
Imperial Reservoir	0.8	5	0.16
Lower Basin river stations	0.6	4	0.15

A major factor in the noted increase is probably due to the higher solubility of uranium as mentioned in Part II. After uranium and radium–226 from uranium mill discharges are assimilated by the Upper Basin sediments, the higher solubility of uranium causes it, and its associated alpha activity, to be leached back to the overlying waters more rapidly than the radium–226 as the sediments are moved downstream. The net result is a proportionate lowering of gross alpha activity in sediments as one proceeds downstream, since the uranium (and its alpha activity) is being released to the overlying waters at the faster rate. Since many other factors affect the uranium concentration in water (primarily liquid wastes from uranium mining and milling operations), it is difficult to substantiate the above theory by examination of uranium concentrations found in Basin waters.

It has been noted that the relatively small number of samples collected in most of the Lower Basin makes it difficult to arrive at statistically reliable figures and relationships. In addition to the number of samples, sampling techniques may also have affected the results. Lake Mead results are averaged from twenty-one different sampling stations while the other reservoirs have been sampled at only one or two locations. Since the reservoir samples are collected from the surface of the bottom deposits, yearly deposition variation and difficulty of returning to the identical sampling point each year may easily affect the results. Nevertheless, the Upper Basin relationships found between radium and gross alpha provide an excellent tool for determining radioactivity conditions in sediments.

A similar and probably more important and useful relationship has been found between radium–226 concentrations in water and sediment collected at the same locations. For background stations, radium–226 in water (pg/liter) averages approximately 4 percent of the radium–226 in sediments (pg/gram). At non-background stations, water concentrations average approximately 13 percent of the sediment concentrations. Except for two figures of 34 and 48 percent at Yuma, Arizona and Bedrock, Colorado, respectively, these figures range from 1.7 to 6.4 percent at background stations and from 8.5 to 22.6 percent at non-background stations. Why these two are so much higher is not evident.

When comparing the levels of radioactivity found in water and sediments in the 1950's as reported in Part I to those reported in Parts II and III, it is evident that there has been a substantial reduction in radioactive contamination of Colorado River Basin streams. The large decreases which can be observed are a result of concerted waste control programs undertaken by the various uranium mills in the Basin since 1960, and demonstrate the great degree of improvement of surface water quality that has been achieved by reasonable and economical pollution abatement practices.

The results also demonstrate the value of a conscientious surveillance program in defining the areas of needed control measures and the subsequent effects and efficiency of these measures. Valuable by-products of the surveillance program have been the knowledge obtained of methods and rates of radioactivity transport and distribution, plus the appearance of definite relationships between radioactive concentrations in the various media discussed in this report.

Analytical Methods

The analytical procedure for radium–226 used in the earlier studies discussed in Part I was a non-emanation technique. Sensitivity was improved in the latter studies by using an emanation technique and larger sample volumes. Composited samples, analysed by the method in Part I were checked against the emanation technique. Uranium determinations were made by fluorometric techniques. Reference 13 provides details of the uranium and emanation methods as well as precision and accuracy figures. Gross alpha determinations were made by internal proportional counting techniques.

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>
> The cooperation and contributions of the various agencies of the States of Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming are also gratefully acknowledged.

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RADIONUCLIDE ANALYSES OF COAST GUARD WATER SUPPLIES, JANUARY–DECEMBER 1963

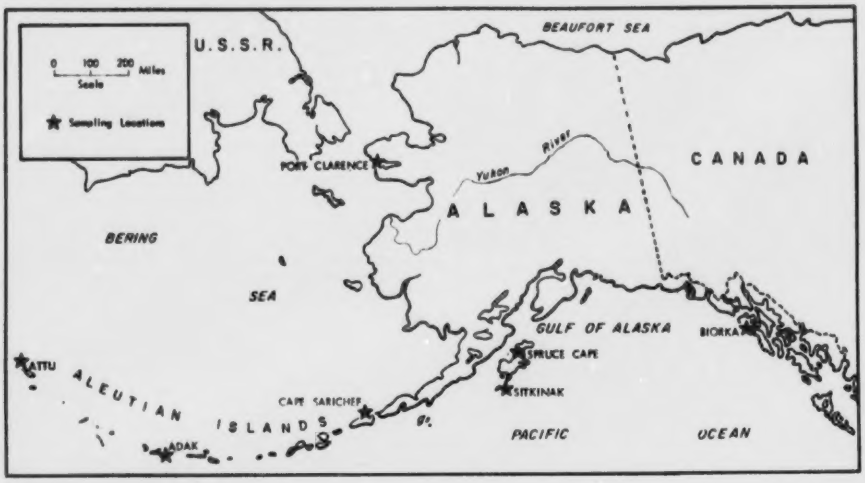
U.S. Coast Guard and Division of Radiological Health, Public Health Service

The Coast Guard Water Sampling Program was initiated in 1957. From 1957 through 1960, monthly samples of several roof-collected rain water cistern supplies were routinely analyzed for beta activity by the Robert A. Taft Sanitary Engineering Center (*1*). Low radioactivity concentrations after 1960, two years after cessation of nuclear weapons tests in 1958, led to the termination of this sampling program.

Since October 1961, drinking water samples have been obtained from seven Coast Guard Loran Stations in Alaska. One gallon samples of potable tap water are collected from each station. Each water supply is an artificial impoundment or lake. Water from these reservoirs is usually filtered, pumped into a tank or cistern and chlorinated before use. The sampling sites are shown in figure 1.

The gross alpha and beta analyses and the selected specific radionuclide analyses reported in table 1 were performed by Southwestern Radiological Health Laboratory at Las Vegas, Nevada. Radionuclide analyses for strontium-90 were carried out only on samples for which this analysis was specifically requested. All other radionuclide analyses were performed by gamma spectroscopy.

The radionuclide analyses reported in table 1 were performed by the Southwestern Radiological Health Laboratory at Las Vegas, Nevada.


U.S.S.R.
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BEAUFORT SEA
CANADA
Yukon River
ALASKA
PORT CLARENCE
BERING
SEA
GULF OF ALASKA
BIORKA
SPRUCE CAPE
SITKINAK
ATTU
ALEUTIAN ISLANDS
CAPE SARICHEF
ADAK
PACIFIC
OCEAN

FIGURE 1.—COAST GUARD LORAN STATION WATER SAMPLING LOCATIONS

TABLE 1.—RADIONUCLIDES IN WATER SAMPLES FROM U.S. COAST GUARD LORAN STATIONS, JANUARY 1963–DECEMBER 1963

[Concentrations in pc/liter]

Alaskan location	Collection date 1963	Gross alpha	Gross beta	Sr^{90}	I^{131}	Ba^{140}	Cs^{137}	Ru^{103}-Ru^{106}	Zr-Nb^{95}
Adak	April 23	4.3	348	[a] —	<10	<10	70	175	900
Attu Island	[b]	0.6	49	—	60	<10	<5	—	<10
	February 5	1.4	33	—	<10	<10	<5	—	<10
	May 7	9.9	80	—	<10	<10	<5	—	55
	June 14	1.9	30	—	—	—	—	—	—
	July 16	<0.1	26	—	<10	<10	<5	—	—
	August 7	0.6	20	—	<10	<10	<5	—	<10
	September 5	<0.1	34	—	<10	<10	<5	—	<10
	October 1	3.9	17	—	<10	<10	<5	—	<10
	November 5	1.1	20	—	<10	<10	<5	<10	<10
	December 3	1.5	21	—	<10	<10	<5	<10	<10
Biorka	August 1	<0.1	142	—	<10	<10	<5	—	—
	December 12	<0.1	44	—	<10	<10	<5	<10	<10
Cape Sarichef	January 22	0.7	43	—	<10	30	<5	—	<10
	May 8	<0.1	12	—	<10	<10	<5	—	<10
	June 10	0.3	49	—	<10	<10	<5	—	<10
	July 15	<0.1	6	—	<10	<10	<5	—	—
	August 8	<0.1	6	—	<10	<10	<5	—	—
	September 12	<0.1	9	—	<10	<10	<5	—	<10
	October 17	<0.1	21	—	<10	<10	<5	—	<10
	November 27	7.2	9	—	<10	<10	<5	<10	<10
	December 10	<0.1	4	—	<10	<10	<5	<10	<10
Port Clarence	January 22	3.3	17	—	<10	<10	<5	—	<10
	May 8	<0.1	7	—	<10	<10	<5	—	<10
	June 8	<0.1	126	6.0	<10	<10	<5	—	<10
	July 6	0.8	85	9.0	<10	<10	5	—	40
	August 8	<0.1	82	—	<10	<10	<5	—	—
	September 12	<0.1	18	—	<10	<10	<5	—	<10
	October 12	<0.1	13	—	<10	<10	<5	—	<10
	December 11	<0.1	44	—	<10	<10	<5	<10	<10
Sitkinak Island	January 30	—	64	—	<10	30	<5	—	50
	April 15	<0.1	44	—	<10	<10	<5	—	<10
	May 22	0.8	51	—	<10	<10	<5	—	<10
	June 3	0.8	41	—	<10	<10	<5	—	<10
	June 14	0.8	26	—	<10	<10	<5	—	<10
	July 22	<0.1	24	—	<10	<10	<5	—	—
	August 7	<0.1	17	—	<10	<10	<5	—	—
	September 12	<0.1	17	—	<10	<10	<5	—	<10
	October 10	3.6	16	—	<10	<10	<5	—	<10
	November 13	26.2	17	—	<10	<10	<5	<10	<10
	December 6	1.6	26	—	<10	<10	<5	<10	<10
Spruce Cape	January 22	0.8	144	—	20	<10	<5	—	90
	May 3	1.7	54	—	<10	<10	<5	—	<10
	June 12	0.3	10	—	—	—	—	—	—
	July 8	<0.1	31	—	<10	<10	<5	—	<10
	August 5	<0.1	34	—	<10	<10	<5	—	—
	September 9	<0.1	34	—	<10	<10	<5	—	<10
	October 3	<0.1	34	—	<10	<10	<5	—	<10
	November 5	1.1	30	—	<10	<10	<5	—	—
	November 12	1.1	11	—	<10	<10	<5	<10	<10
	December 9	2.8	38	—	<10	<10	<5	<10	<10

[a] Dash indicates no analysis.
[b] Date of collection unknown (counted on January 7, 1963).

REFERENCE

(*1*) Straub, C. P.: Statement on New Data on Uptake in Milk, Food, and Human Bone, *Joint Committee on Atomic Energy Hearings on Fallout From Nuclear Weapons Tests, 2:* 990 (May 1959).

Previous coverage in *Radiological Health Data:*

Period	Issue
October-November 1959	*June 1960*
October-December 1959	*July 1960*
Fourth quarter 1959, and First and second quarters 1960	*August 1961*
October 1961-April 1962	*October 1962*
May-December 1962	*August 1963*

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Section IV—Other Data

ENVIRONMENTAL LEVELS OF RADIOACTIVITY AT ATOMIC ENERGY COMMISSION INSTALLATIONS

The U. S. Atomic Energy Commission receives from its contractors periodic reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant perimeter surveys are required.

Summaries of environmental radioactivity data for 23 AEC installations have appeared periodically in *RHD* since November 1960. Summaries follow for Bettis Atomic Power Laboratory, Mound Laboratory and Shippingport Atomic Power Station.

Releases of radioactive materials from these installations for the periods covered in the reports below are regulated in accordance with AEC standards as set forth in the Federal Register Title 10—Part 20 (*1*). The appropriate concentration standards are given in table 1.

TABLE 1.—MAXIMUM PERMISSIBLE CONCENTRATIONS PERTAINING TO ENVIRONMENTAL MONITORING AT BETTIS ATOMIC POWER LABORATORY, MOUND LABORATORY AND SHIPPINGPORT ATOMIC POWER STATION [a]

Radionuclide	Air (pc/m^3)	Water (pc/liter)
Mixture, if Sr^{90}, I^{129}, Pb^{210}, Po^{210}, Ra^{223}, Ra^{226}, Ra^{228}, Pa^{231}, and Th-nat are not present [b]	—	2,000
Mixture, if Sr^{90}, I^{129}, Pb^{210}, Ac^{227}, Ra^{228}, Pa^{230}, Pu^{241}, Bk^{249} are not present [b]	100	—
Hydrogen-3 (tritium)	200,000	3,000,000
Strontium-90	10	100
Xenon-133	300,000	—
Polonium-210	20	700
Uranium natural	2	20,000
Plutonium-239	0.06	5,000
Mixture of unidentified radionuclides	0.04	10

[a] The concentration standards given here were taken from the Atomic Energy Commission's regulation 10 CFR Part 20, Federal Register, (*1*).

[b] "Not present" implies that the concentration of the nuclide is small compared with its appropriate MPC. According to Federal Register, Title 10, Part 20, (*1*), a group of nuclides may be considered not present if the ratio of each nuclide to its appropriate MPC is equal to or less than 1/10 and if the sum of these ratios for the group in question is equal to or less than ¼.

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1. BETTIS ATOMIC POWER LABORATORY JULY–DECEMBER 1963[1]

Westinghouse Electric Corporation

The Bettis Atomic Power Laboratory (BAPL), operated for the Atomic Energy Commission by Westinghouse Electric Corporation, was established in 1949 to conduct research and development operations related to naval atomic propulsion systems and the central station atomic power reactor at Shippingport, Pennsylvania.

The data for the 6-month period from July through December 1963 are given in table 2. Figure 1 shows the location of the sampling sites.

Liquid Radioactive Waste

Liquid effluent discharged from the Laboratory is sampled continuously and composite samples are analyzed weekly for gross alpha and gross beta-gamma activity and quarterly for strontium–90 activity. In addition, analysis for total uranium alpha activity is performed whenever the combined gross alpha and beta-gamma activities exceed 2,000 pc/liter.

The average concentration of gross radioactivity, including fallout, in the liquid effluent during the second six months of 1963 was 120 pc/liter. This was not significantly different from the first six month's average concentration of 150 pc/liter. The average concentration of strontium–90 for the second quarter of 1963 was 5.9 pc/liter. The average concentration of strontium–90 for the third quarter of 1963 was 23 pc/liter.

The strontium–90 analyses for the fourth quarter 1963 have not been completed.

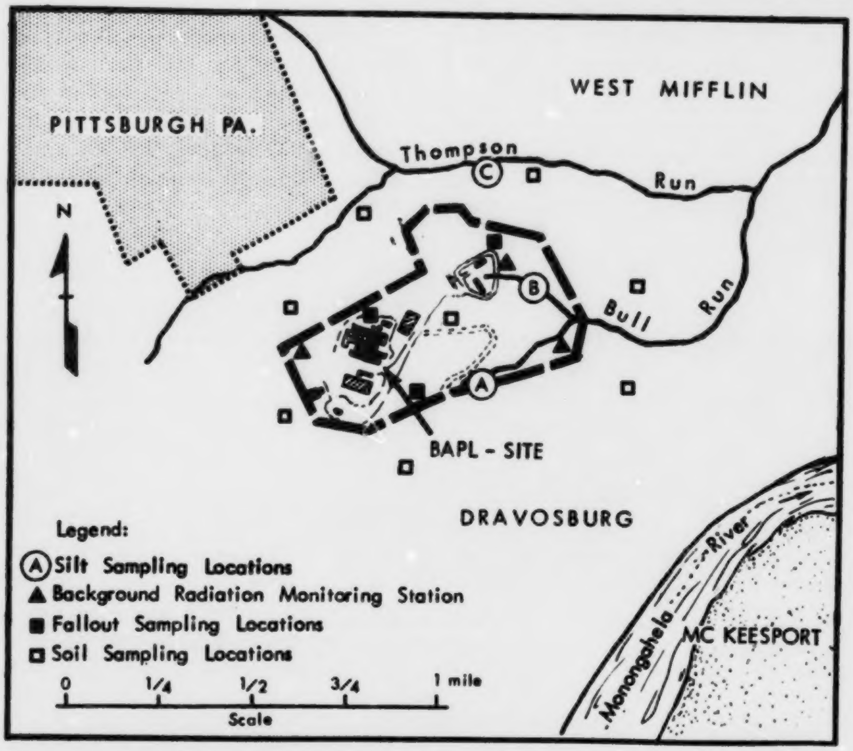
WEST MIFFLIN
PITTSBURGH PA.
Thompson
C
Run
N
B
Bull
Run
A
BAPL - SITE
DRAVOSBURG
Legend:
Ⓐ Silt Sampling Locations
▲ Background Radiation Monitoring Station
■ Fallout Sampling Locations
□ Soil Sampling Locations
0
1/4
1/2
3/4
1 mile
Scale
River
Monongahela
MC KEESPORT

FIGURE 1.—BETTIS ATOMIC POWER LABORATORY SAMPLING STATIONS

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[1] Data and information summarized from reports to the Pennsylvania Department of Health entitled *Environmental Radioactivity at the Bettis Atomic Power Laboratory: PNRO-DEV-128.* The reports were prepared by BAPL's Industrial Hygiene Department and transmitted through the AEC Pittsburgh Naval Reactors Office.

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TABLE 2.—RADIOACTIVITY IN THE BAPL ENVIRONMENT, SECOND-HALF 1963

Type of measurement	3rd quarter	4th quarter
Liquid wastes (pc/liter)		
Gross activity [a]	152	89
Strontium-90	23	[b] —
Beta-gamma dose rate (mrad/hr)		[c] .021
Beta activity in fallout (mc/mi²/mo)	92	[d] 15
Stream silt (pc/gram)		
Alpha: Station A	95	38
Station B	17	21
Station C	19	36
Beta: Station A	85	37
Station B	19	25
Station C	16	7.3

[a] An environmental MPC of 2,000 pc/liter is used as the standard for liquid wastes effluent (see table 1).

[b] The fourth quarter strontium-90 has not been determined as of present.

[c] Beta-gamma activity values are semi-annual averages.

[d] Analysis for December not complete.

Background Monitoring Stations

Four background monitoring stations are in continuous operation on the Laboratory property. Three of the stations are located at the perimeter of the Laboratory and one station is centrally located with respect to the main Laboratory area. These stations continually measure and record the external beta-gamma radiation level, the external gamma radiation level and the beta-gamma activity of particulates in air as collected by a continuous air monitor of the moving filter type. An air sample is continuously collected at two of the stations. The filters removed from the high volume air samplers are retained for specific analysis when required to identify the nature of the airborne activity. External gamma activity for the three perimeter stations are given in table 2.

Background beta-gamma radiation intensities averaged 0.02 mr/hr during this period. This is not significantly different from the background radiation intensities measured during the first six months of 1963.

Soil samples

Soil samples are collected at eight locations on and off site and are retained for a period of two years. These samples are analyzed for radioactivity only on an "as required" basis. No analyses were required during the 6-month period ending December 1963.

Stream Silt

Stream silt samples are collected quarterly at three locations described as follows:

Location A: Bull Run downstream from the point where the water leaves the main laboratory area at the first point where silt has accumulated.

Location B: C-Area effluent downstream from its origin at the first point where silt has accumulated.

Location C: Thompson Run downstream from the junction of the High Temperature Test Facility effluent and Thompson Run at the first point where silt has accumulated.

These samples are analyzed quarterly for gross alpha activity and gross beta-gamma activity. Table 2 shows that samples from location A tend to have slightly higher activity than samples from location B and C.

Fallout

Fallout samples, collected at three locations at the perimeter of the Laboratory over a period of one month in high-wall stainless steel pots, are analyzed for gross alpha activity and gross beta-gamma activity.

The average concentration of radioactive fallout for five months during the last half of 1963 was 61 mc/mi²/mo. There was a decrease in fallout activity during this period as compared to the first six months of 1963.

Recent coverage in *RHD:*

Period	Issue
January to June 1961	*April 1962*
July 1961 to June 1962	*April 1963*
July 1962 to June 1963	*April 1964*

2. MOUND LABORATORY, JULY 1963–DECEMBER 1963

Monsanto Research Corporation

Of the radionuclides in use at Mound Laboratory, only polonium–210, plutonium–239, and hydrogen–3 (tritium) are potential environmental contaminants. No measurable amounts of penetrating radiation such as gamma or hard beta have contributed to the environment contamination by the Laboratory during the period covered by this report.

The environmental monitoring program, conducted by the Monsanto Research Corporation, is planned and coordinated with regard to all of the various projects performed in the Laboratory. Water and air monitoring methods and results are discussed below.

Air Monitoring

A continuous air monitor for measurement of tritium and particulate air sampling equipment for measurement of alpha activity are mounted on a one-ton panel truck for use in the routine monitoring of the environmental air at 95 locations selected within a radius of 20 miles. The choice of sites on a given day depends on the wind direction at the time of collection.

During the 6-month period ending December 1963, 144 samples were taken for determination of tritium in air. In all cases tritium was nondetectable.

Monitoring for possible polonium–210 and plutonium–239 released to the environment is accomplished by determination of long-lived gross alpha activity on filter paper samples. Counting is done in a low-background proportional counter. Sufficient delay time is allowed after collection to minimize interference from the daughter products of radon and thoron. The measured concentrations of alpha activity in air are summarized in table 3. No specific determinations of polonium–210 or plutonium–239 were made, since the alpha activity remained substantially below the environmental MPC's for these nuclides (see table 1). It may be observed that the largest difference between upwind and downwind average alpha activity was 0.0028 pc/m^3 for second half 1963. The gross alpha air concentration averaged over the 6-month period was 9.5 percent of the environmental MPC for plutonium.

Water Monitoring

Liquid radioactive waste materials from polonium operations at the Laboratory are processed in a special waste disposal plant designed to reduce radioactivity to a concentration level at which it may be discharged to the Great Miami River (station 2, figure 2). Liquid waste from these activities is small in volume, is handled separately as a packaged waste and is not discharged to the river. Helium–3, which is purified at the Mound Laboratory, yields small quantities of tritium. Liquid wastes from this work, also small in volume, are treated separately (diluted with water when necessary) to assure that the radioactivity content is below the maximum permissible concentration for discharge to the Great Miami River.

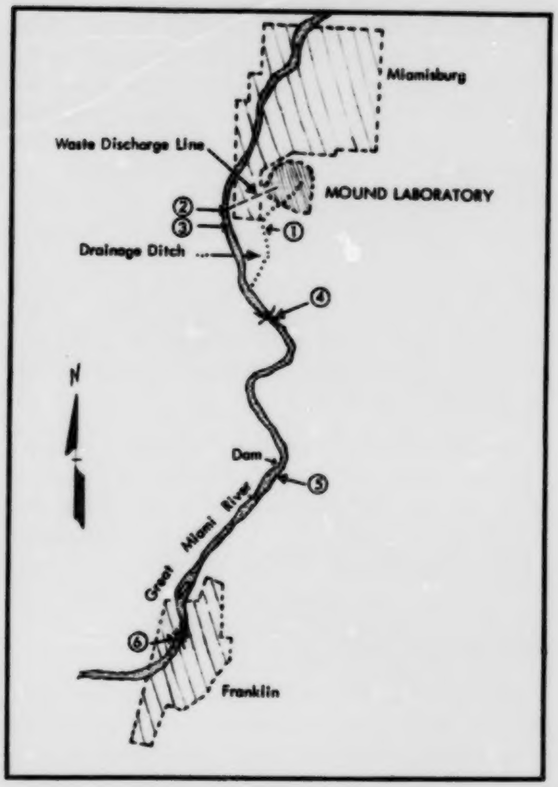

FIGURE 2.—WATER SAMPLING LOCATIONS IN GREAT MIAMI RIVER, MOUND LABORATORY

Table 3.—LONG-LIVED ALPHA CONCENTRATIONS IN AIR IN THE MOUND LABORATORY ENVIRONMENT

[Average concentration in pc/m^3]

Direction from laboratory relative to wind	Second half 1963	
	No. of samples	Alpha
Upwind	41	0.0027
Downwind	250	0.0055

Weekly water samples are collected from a drainage ditch and five locations along the Great Miami River as shown in figure 2. The drainage ditch carries away all storm sewer water and liquid tritium wastes from the plant site. Sampling location number 2 is located at the point of discharge of the laboratory effluent to the Great Miami River, and number 6 is five miles downstream from the effluent outlet.

All of the river samples are analyzed for polonium-210. The drainage ditch samples and some of the river samples are analyzed for tritium. Average concentrations of tritium and polonium-210 are given in table 4. The highest polonium-210 concentration during the 6-month period was 120 pc/liter in a sample of Laboratory effluent (station 2) collected during the second half of 1963. This represents 16 percent of the MPC for polonium-210 (see table 1). The highest tritium value found in a sample was equal to the MPC, but the average was 4 percent of the MPC.

Table 4.—OFF SITE WATER MONITORING FOR POLONIUM-210 AND TRITIUM FROM MOUND LABORATORY [a]

[Average concentration in pc/liter]

Nuclide and station number (see figure 2)	Second half 1963	
	Number of samples	Concentration
Polonium-210		
2 (effluent)	17	11.2
3	17	2.2
4	17	2.7
5	17	2.2
6	17	2.7
Hydrogen-3 (tritium)		
1 (drainage ditch)	17	500,000
2 (effluent)	17	50,000
4	17	50,000

[a] See table 1 for applicable environmental MPC values.

Recent coverage in *RHD:*

Period	Issue
January-June 1961	*January 1962*
July-December 1961	*June 1962*
January-June 1962	*March 1963*
July 1962-June 1963	*April 1964*

3. SHIPPINGPORT ATOMIC POWER STATION
JULY 1963–DECEMBER 1963

Duquesne Light Company,
Shippingport, Pennsylvania

Environmental radiation monitoring at the Shippingport Atomic Power Station began with a two-year preoperational survey program to establish background levels.

Following initial operation of the plant in December 1957, this program was continued as originally conceived through the third quarter of 1961, when it was determined that fewer sampling locations closer to the plant would provide equal or better evaluation of the effects of plant operation on the environment.

Release of Radioactive Materials to the Atmosphere

Controlled releases of xenon-133 were made periodically at a concentration of 140,000 pc/m^3 at the stack. A total of 351 mc of xenon-133 were discharged during the second half of 1963.

The exhaust from an incinerator for burning contaminated combustible material is passed through a wet scrubber and a high efficiency filter before entering the stack. The average gross radioactivity of incinerator effluent during operation ranged from 5 pc/m^3 to 42 pc/m^3 during the second half of 1963.

Air Monitoring

Airborne particulates are sampled at three area monitoring stations by means of a continuously moving paper tape sampler with an end-window Geiger-Mueller detector and recorder. Since only one-half hour decay time is allowed before counting, hence, naturally-occurring radon and thoron daughters are present. Six-month average activities shown in table 5 are for Area monitoring stations 1, 2, and 3, located 150 yards southeast, 150 yards west and one-half mile north-northwest of the stack, respectively.

TABLE 5.—GROSS BETA IN AIR

[Average concentrations in pc/m³]

Station number	Second half 1963
1	2.2
2	2.6
3	2.4

Fallout Sampling

Monthly pot samples were collected at each of the three area monitoring stations (same locations as for air). Gross beta average monthly deposition rates are given in table 6.

TABLE 6.—GROSS BETA IN FALLOUT

[Average monthly deposition in nc/m²]

Station number	Second half 1963
1	113
2	132
3	144

Liquid Radioactive Waste Disposal

Continuous controlled discharges of tritium and unidentified radioactive wastes are made into the Ohio River. The quantities of discharge and average effluent concentration are given in table 7.

TABLE 7.—LIQUID WASTES DISCHARGED INTO THE OHIO RIVER

	Tritium	Unidentified radioactivity
	Second half 1963	Second half 1963
Total discharge (mc)	785	88.7
Average of monthly average concentrations of effluent (pc/liter)	53	2.5

Ohio River Water Monitoring

River water samples were collected by a continuous sampler upstream at the Shippingport condenser cooling water intake and by grab sampling downstream at the condenser cooling water outfall. (The downstream continuous sampler was not functioning.) These samples were analyzed weekly for both alpha and beta, suspended and dissolved radioactivity. The six-month averages of these measurements are given in table 8.

TABLE 8.—RADIOACTIVITY IN OHIO RIVER WATER SECOND HALF 1963

[Average concentrations in pc/liter]

Type of radioactive material	Upstream samples			Downstream samples		
	Maximum	Minimum	Average	Maximum	Minimum	Average
Alpha:						
Suspended solids	0.47	0.08	0.26	0.35	0.09	0.18
Dissolved solids	3.49	0.00	1.15	2.87	0.07	0.16
Total solids	3.96	0.08	1.41	3.22	0.16	0.34
Beta:						
Suspended solids	25.5	2.99	8.76	20.5	3.31	7.75
Dissolved solids	129.4	16.9	53.6	110.2	21.5	47.6
Total solids	154.9	19.9	62.4	130.7	24.8	55.4

REFERENCE

(1) U.S. Atomic Energy Commission: *Rules and Regulations, Standards for Protection Against Radiation*, Title 10 CFR 20, Government Printing Office, Washington, D. C.

Previous coverage in *RHD:*

Period	Issue
1959	*July 1960*
First quarter 1960	*December 1960*
Second quarter 1960	*January 1961*
Third and fourth quarters 1960	*October 1961*
First and second quarters 1961	*April 1962*
Second half 1961 and first half 1962	*May 1963*
July 1962-June 1963	*March 1964*

REPORTED NUCLEAR DETONATIONS, OCTOBER 1964

During October 1964, four United States nuclear tests were announced by the Atomic Energy Commission and one nuclear test was announced by Communist China.

The first of the U. S. tests was of low intermediate yield (20–200 kilotons), and was conducted underground on October 2, at the Nevada Test Site. Low-yield tests (less than 20 kilotons) were conducted underground at the Site on October 16 and October 31, respectively. The fourth U. S. test was a deep underground nuclear explosion (equivalent to about 5000 tons of TNT) on October 22 in the Tatum Salt Dome near Hattiesburg, Mississippi. This event, nicknamed *Salmon*, was the first of 3 planned in the series designated as Project Dribble, which in turn is a part of the Vela Uniform Program sponsored by the Advanced Research Projects Agency of the Department of Defense. Vela Uniform is the nation's seismic research program designed to improve our capability to detect, identify and locate underground nuclear detonations.

The detonation of the Chinese Communist device took place on October 16 and preliminary analysis of airborne radioactive debris indicates it involved a low-yield fission device employing uranium–235.

Arbitrary *RHD* reference numbers applied to the four U. S. tests are 167 through 170 in chronological order; the Chinese test is given the identifying designation C–1.

The Public Health Service reported that small amounts of iodine–131 had been detected in some Pasteurized Milk Network milk samples during the last week of October.

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RADIOLOGICAL HEALTH DATA

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DECEMBER 1964

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service • Division of Radiological Health

Section I—Air and Fallout

FISSION PRODUCT BETA ACTIVITY IN AIRBORNE PARTICULATES AND PRECIPITATION

Continuous surveillance of gross beta activity in air and precipitation provides one of the earliest and most sensitive indications of changes in environmental fission product activity. Although this surveillance does not provide enough information to assess human radiation exposure from fallout, it is widely used as the basis of alerting systems for determining when to intensify monitoring in other phases of the environment.

Surveillance data from a number of national programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. Data provided by programs of the Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization are presented individually in tabular form and are also compared in beta concentration isograms.

1. Radiation Surveillance Network
August 1964

Division of Radiological Health,
Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Surveillance Network (RSN) of the PHS Division of Radiological Health which regularly gathers samples from 73 stations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The alerting function of the network is provided by field estimates of the gross beta activity of airborne particulates on the filters. These determinations are performed about 5 hours after the end of the sampling period to allow for decay of naturally-occurring radon daughters. The network station operators regularly submit their field estimates to the Radiation Surveillance Center, Division of Radiological Health, Washington, D. C. These field estimates are reported elsewhere on a monthly basis (*1*). When unusually high air levels are reported, appropriate Federal and State officials are promptly notified.

Air

Airborne particulates are collected continuously on a carbon-loaded cellulose dust filter 4 inches in diameter. A volume of about 1800 cubic meters of air is drawn through the filter during the 24-hour sampling period by a high volume centrifugal blower.

The filters are forwarded to the Radiation Surveillance Network laboratory in Rockville, Maryland, where the gross beta activity is measured using a thin-window, gas-flow proportional counter, calibrated with a Sr^{90}–Y^{90} standard. Each filter is counted at least 3 days after the end of the sampling period and again 7 days later. The initial 3-day aging of the sample eliminates interference from naturally-occurring radon and thoron daughters. By using the two counts and the Way-Wigner formula (*2*), the age of fission products is estimated, and the activity extrapolated to the

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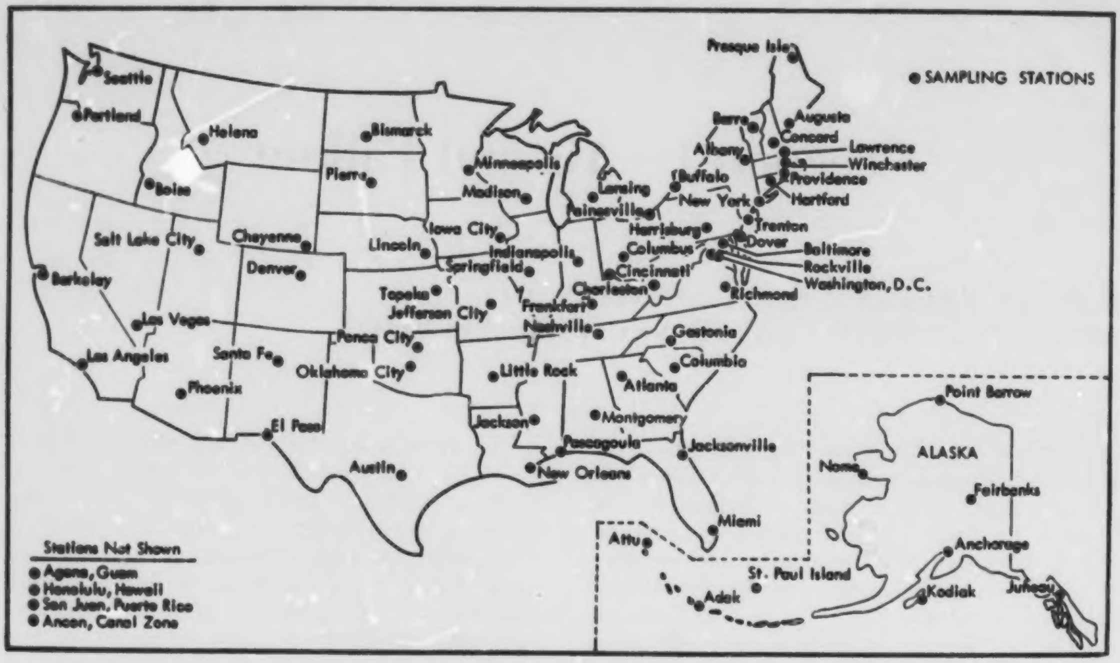
SAMPLING STATIONS
Seattle
Portland
Helena
Boise
Bismarck
Pierre
Minneapolis
Madison
Lansing
Painesville
Buffalo
New York
Presque Isle
Barre
Augusta
Concord
Albany
Lawrence
Winchester
Providence
Hartford
Trenton
Dover
Baltimore
Rockville
Washington, D.C.
Richmond
Harrisburg
Columbus
Cincinnati
Charleston
Frankfort
Nashville
Gastonia
Columbia
Atlanta
Montgomery
Jacksonville
Miami
Pascagoula
New Orleans
Jackson
Little Rock
Salt Lake City
Cheyenne
Denver
Lincoln
Iowa City
Indianapolis
Springfield
Topeka
Jefferson City
Berkeley
Las Vegas
Los Angeles
Santa Fe
Phoenix
Ponca City
Oklahoma City
El Paso
Austin
Point Barrow
ALASKA
Nome
Fairbanks
Anchorage
Attu
St. Paul Island
Adak
Kodiak
Juneau
Stations Not Shown
Agana, Guam
Honolulu, Hawaii
San Juan, Puerto Rico
Ancon, Canal Zone

FIGURE 1.—RADIATION SURVEILLANCE NETWORK SAMPLING STATIONS

time of collection.[1] The daily concentrations and estimated ages of selected samples are reported by the PHS in a monthly RSN report (*1*). The August 1964 average gross beta concentrations in air for RSN stations are given in table 1. Time profiles of gross beta activity in air for eight RSN stations are shown in figure 2.

Precipitation

Continuous sampling for total precipitation is conducted at most stations on a daily basis, using funnels with collection areas of 0.4 square meter. A 500-ml aliquot of the collected precipitation is evaporated to dryness, and the residue is forwarded to the laboratory for analysis. If the collected sample is between 200 and 500 ml, the entire sample is evaporated. When a sample is smaller than 200 ml (equivalent to 0.5 mm or 0.02 inches of rainfall), the volume of precipitation is reported, but no analysis is made.

In the laboratory the gross beta activity in precipitation is determined by counting the evaporated sample by the same method used for analyzing the air filters, including the extrapolation to time of collection. Deposition for the sample is determined by:

$$D=\frac{CP}{1000}$$

where D is the deposition in nc/m^2, C is the concentration in pc/liter, and P is the depth of precipitation in mm. The individual values of deposition and depth of precipitation are totaled for the month, and the average concentration for the month, $\overline{C}$, is determined by:

$$\overline{C}=\frac{\Sigma D}{\Sigma P}\times 1000$$

The August 1964 average concentrations and total depositions are given in table 1.

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[1] If a sample contains a mixture of fresh and old fission products, the age estimated by the Way-Wigner formula is some intermediate value and cannot be used for estimating date of formation.

TABLE 1.—GROSS BETA ACTIVITY IN SURFACE AIR AND PRECIPITATION, AUGUST 1964

Station location		Air surveillance				Precipitation measurements		
		Number of samples	Gross beta activity (pc/m³)			Last profile in *RHD*	Average concentration (pc/liter)	Total deposition (nc/m²)
			Maximum	Minimum	Average [a]			
Ala:	Montgomery	21	0.95	<0.10	0.36	Aug 64	200	23.4
Alaska:	Adak	13	0.43	<0.10	0.19	Nov 64		
	Anchorage	24	0.21	<0.10	0.12	Jul 64	270	11.7
	Attu Island	31	0.52	<0.10	0.20	Dec 64		
	Fairbanks	27	0.59	<0.10	0.23	Aug 64	220	15.6
	Juneau	10	0.30	<0.10	0.14	Sep 64	200	8.0
	Kodiak	23	0.54	<0.10	0.10	Oct 64		
	Nome	[b]						
	Point Barrow							
	St. Paul Island	28	0.42	<0.10	0.13	Mar 64		
Ariz:	Phoenix	31	0.91	<0.10	0.26	Sep 64		
Ark:	Little Rock	31	0.92	<0.10	0.44	Sep 64	200	21.4
Calif:	Berkeley	20	0.46	<0.10	0.21	Oct 64	[c]—	—
	Los Angeles	21	0.58	0.20	0.38	Feb 64	—	—
Canal Zone:	Ancon	16	0.27	<0.10	0.12	Nov 64		
Colo:	Denver	28	1.6	0.15	0.66	Oct 64	460	10.2
Conn:	Hartford	30	1.7	<0.10	0.71	Oct 64	250	11.9
Del:	Dover	20	1.8	0.24	0.86	Aug 64		
D. C:	Washington	30	2.7	0.16	0.83	Aug 64	270	10.6
Fla:	Jacksonville	27	1.4	<0.10	0.38	Sep 64	210	35.5
	Miami	28	1.4	<0.10	0.48	Oct 64	210	18.1
Ga:	Atlanta					Jul 64	210	16.1
Guam:	Agana	31	0.14	<0.10	0.10	Apr 64		
Hawaii:	Honolulu	31	0.66	<0.10	0.31	Dec 64	260	3.8
Idaho:	Boise	31	1.9	0.16	0.72	Dec 64	230	0.5
Ill:	Springfield	29	1.1	0.16	0.63	Mar 64	270	7.4
Ind:	Indianapolis	29	2.2	0.24	0.65	Jul 64	450	11.2
Iowa:	Iowa City	30	1.1	<0.10	0.55	Nov 64	240	18.3
Kans:	Topeka	14	0.87	0.24	0.45	Jul 64	210	18.6
Ky:	Frankfort	30	1.2	0.15	0.66	Feb 64	320	4.9
La:	New Orleans	28	0.52	<0.10	0.22	Mar 64	200	27.1
Maine:	Augusta	30	1.6	<0.10	0.76	Mar 64	250	34.5
	Presque Isle	27	1.5	<0.10	0.62	Nov 64		
Md:	Baltimore	21	1.5	<0.10	0.73	Oct 64	330	13.6
	Rockville	05	0.86	0.54	0.79	Mar 64		
Mass:	Lawrence	31	2.1	<0.10	0.81	Aug 64	390	13.5
	Winchester	30	2.2	<0.10	0.81	Dec 64	630	21.7
Mich:	Lansing	31	2.8	0.24	0.90	Feb 64	300	29.1
Minn:	Minneapolis	31	0.80	<0.10	0.34	Mar 64	220	29.2
Miss:	Jackson	31	1.2	<0.10	0.42	Apr 64	230	21.4
	Pascagoula					Dec 64		
Mo:	Jefferson City	31	0.75	0.15	0.42	Jul 64	<200	4.9
Mont:	Helena	28	1.4	0.13	0.72	Nov 64	310	9.0
Nebr:	Lincoln	12	0.73	<0.10	0.34			
Nev:	Las Vegas	28	1.4	0.13	0.52	Aug 64		
N. H:	Concord	21	2.2	<0.10	0.84	Feb 64		
N. J:	Trenton	31	1.5	0.21	0.72	Apr 64		
N. Mex:	Santa Fe	29	1.9	<0.10	0.43	Nov 64	230	8.8
N. Y:	Albany	21	2.1	<0.10	0.82	Jul 64	270	4.7
	Buffalo	21	2.1	<0.10	0.92	Nov 64		
	New York	27	1.8	0.22	0.87	Dec 64		
N. C:	Gastonia	30	1.5	<0.10	0.63	Nov 64	220	25.3
N. Dak:	Bismarck	29	1.5	0.18	0.62	Feb 64	290	6.8
Ohio:	Cincinnati	20	1.2	0.28	0.62	Aug 64		
	Columbus	31	2.0	0.16	0.80	Apr 64	450	17.8
	Painesville	31	2.2	0.16	0.96	Oct 64	290	22.3
Okla:	Oklahoma City	28	0.81	<0.10	0.24	Apr 64	200	6.0
	Ponca City	30	0.79	<0.10	0.28	Oct 64	204	52.4
Ore:	Portland	31	2.1	0.17	0.54	Oct 63	230	6.7
Pa:	Harrisburg	30	3.0	<0.10	0.85	Jul 64	200	2.5
P. R:	San Juan	06	0.82	<0.10	0.52	Mar 64	200	9.8
R. I:	Providence	29	3.6	<0.10	0.92	Jan 64	260	14.8
S. C:	Columbia	28	0.96	<0.10	0.45	Dec 64	250	13.9
S. Dak:	Pierre	30	1.1	0.14	0.47	Sep 64	<200	2.3
Tenn:	Nashville	31	1.2	<0.10	0.56	Jan 64	240	32.2
Tex:	Austin	31	0.45	<0.10	0.19	Aug 64	200	8.7
	El Paso	30	1.3	0.12	0.33	Jan 64	220	7.2
Utah:	Salt Lake City	31	0.98	0.25	0.49	Aug 61	970	5.2
Vt:	Barre	31	2.4	<0.10	0.91	Sep 64	300	28.8
Va:	Richmond	31	1.2	0.12	0.52	Sep 64	370	24.5
Wash:	Seattle	30	0.73	<0.10	0.18	Jul 64	230	6.4
W. Va:	Charleston	30	1.3	0.17	0.71	Dec 64	290	15.8
Wis:	Madison	30	1.4	0.15	0.71	Sep 64	240	18.1
Wyo:	Cheyenne	31	1.2	0.21	0.58	Aug 64	<200	8.5
Network summary		1,857	3.5	<0.10	0.53		279	16.4

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[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes. If the <0.10 values represent more than 10 percent of the average, a less-than sign is placed before the average.

[b] Blank indicates no report received.

[c] Dash indicates no precipitation sample collected.

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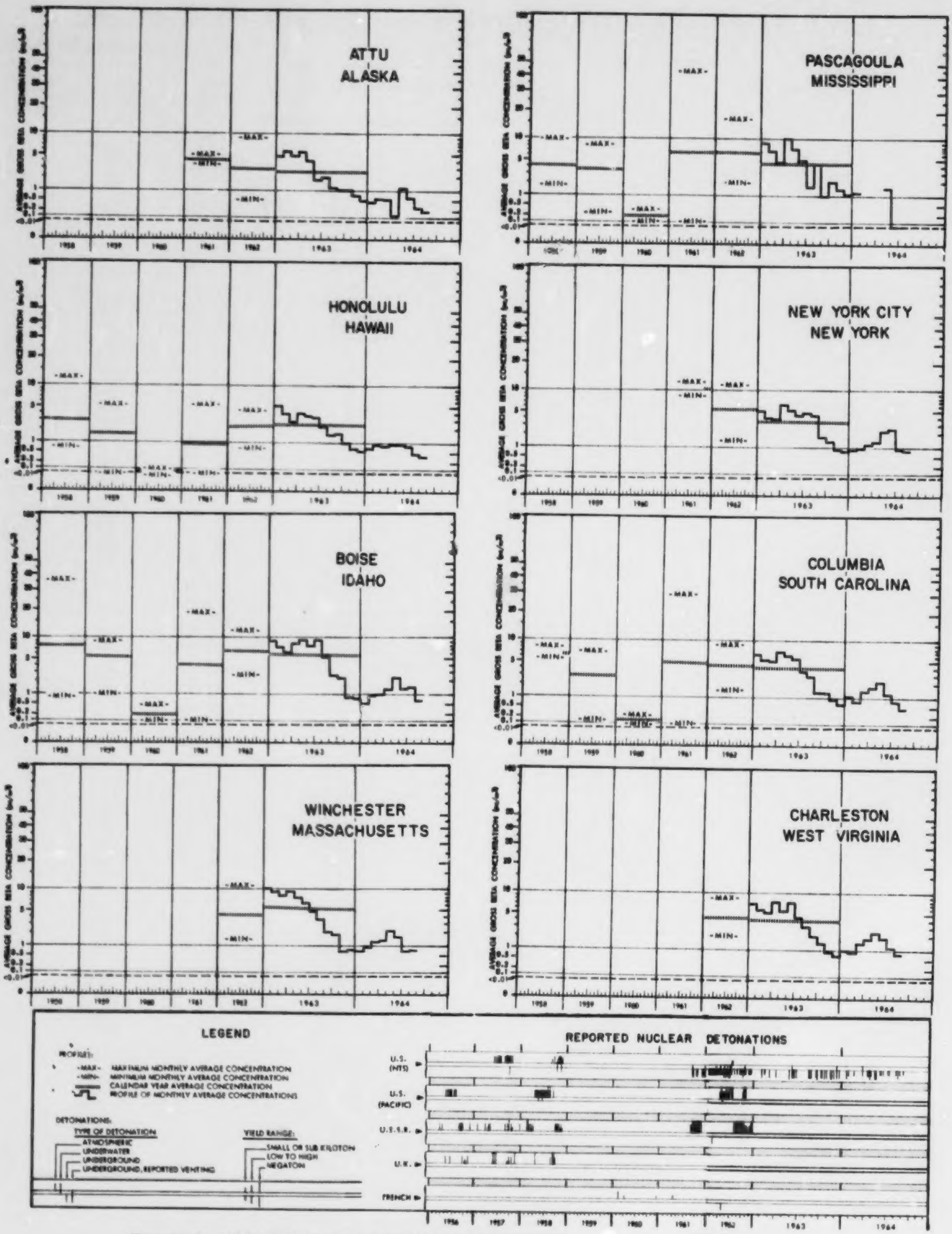

FIGURE 2.—MONTHLY AND YEARLY PROFILES OF BETA ACTIVITY IN AIR—RADIATION SURVEILLANCE NETWORK, 1958—AUGUST 1964

2. Canadian Air Monitoring Program[2]
August 1964

Department of National Heatlh and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 2), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*3–7*).

Air

Each air sample involves the collection of particulates from about 650 cubic meters of air drawn through a high-efficiency 4-inch-diameter filter during a 24-hour period. These filters are sent daily to the Radiation Protection Division Laboratory in Ottawa. At the laboratory, a 2-inch-diameter disk is cut from each filter and counted with a thin-end-window, gas-flow, Geiger-Mueller counter system, calibrated with a Sr^{90}–Y^{90} standard. Four successive measurements are made on each filter to permit correction for natural activities and for the decay of short-lived fission products. The results are extrapolated to the end of the sampling period. Canadian air data for August 1964 are given in table 2 and presented in conjunction with U. S. and Mexican data by an isogram map (figure 5).

Table 2.—GROSS BETA ACTIVITY IN SURFACE AIR AND PRECIPITATION, CANADA

Station	Air surveillance				Precipitation data	
	Number of samples	Gross beta activity (pc/m³)			Average concentration (pc/liter)	Total deposition (nc/m²)
		Maximum	Minimum	Average		
Calgary	30	1.4	0.1	0.7	2,380	12.7
Coral Harbour	31	0.8	0.1	0.3	282	12.8
Edmonton	31	1.0	0.1	0.5	367	26.0
Ft. Churchill	29	0.9	0.1	0.4	436	13.3
Ft. William	30	1.0	0.1	0.4	255	26.7
Fredericton	30	1.3	0.1	0.5	169	19.3
Goose Bay	31	1.3	0.1	0.5	217	22.6
Halifax	30	1.1	0.1	0.5	303	24.0
Inuvik	31	1.0	0.1	0.4	355	6.8
Montreal	31	2.2	0.1	0.7	208	19.5
Moosonee	31	1.2	0.1	0.4	178	30.8
Ottawa	31	2.6	0.1	0.6	380	13.2
Quebec	31	1.9	0.1	0.7	222	32.0
Regina	31	1.2	0.1	0.7	370	19.0
Resolute	29	0.8	0.0	0.2	3,350	79.9
St. John's, Nfld	30	1.0	0.1	0.4	175	27.3
Saskatoon	31	1.3	0.2	0.7	425	24.9
Sault Ste. Marie	29	1.8	0.1	0.6	249	20.7
Toronto	30	1.8	0.1	0.7	181	26.1
Vancouver	31	0.9	0.1	0.3	520	19.6
Whitehorse	31	1.0	0.1	0.3	279	14.3
Windsor	31	1.6	0.1	0.6	166	24.8
Winnipeg	29	0.9	0.2	0.5	286	25.1
Yellowknife	30	1.1	0.2	0.6	1,207	12.0
Network summary		2.6	0.0	0.5	540	23.1

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[2] Data from *Radiation Protection Programs Vol 2, No. 9:* 11–24, Radiation Protection Division, Canadian Department of National Health and Welfare, Ottawa, Canada (Sept. 1964).

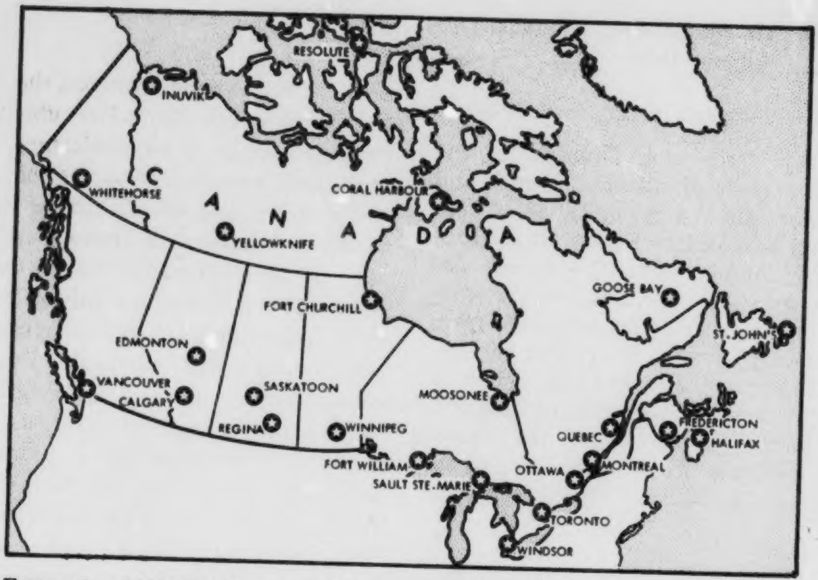
RESOLUTE
INUVIK
WHITEHORSE
C A N A D A
CORAL HARBOUR
YELLOWKNIFE
GOOSE BAY
FORT CHURCHILL
ST. JOHN'S
EDMONTON
VANCOUVER
CALGARY
SASKATOON
REGINA
WINNIPEG
MOOSONEE
QUEBEC
FREDERICTON
HALIFAX
FORT WILLIAM
SAULT STE. MARIE
OTTAWA
MONTREAL
TORONTO
WINDSOR

FIGURE 3.—CANADIAN AIR AND PRECIPITATION SAMPLING STATIONS

Precipitation

The amount of radioactive fallout deposited on the ground is determined from measurements on material collected in special polyethylene-lined rainfall pots. The collection period for each sample is one month. After transfer of the water to the sample container, the polyethylene liner is removed, packed with the sample, and sent to the laboratory.

Strontium and cesium carriers are added to all samples on arrival at the laboratory. Other carriers are also added to selected samples according to the specific radionuclides to be determined. The samples are then filtered and the filtrate evaporated to near dryness. The filter paper containing insoluble matter is ignited together with the polyethylene liner at 450° C. The ash is combined with the soluble fraction, transferred to a glass planchet, evaporated under an infra-red lamp and then counted with a thin-end-window Geiger-Mueller counter calibrated with a Sr^{90}–Y^{90} source. Gross beta activities for August 1964 samples are given in table 2. Radionuclide analyses are reported quarterly in *RHD*.

3. Mexican Air Monitoring Program August 1964

National Commission of Nuclear Energy

The Radiation Surveillance Network of Mexico was established by the *Comisión Nacional de Energía Nuclear* (CNEN), Mexico City. From 1952 to 1961 the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN (*8–12*).

In 1961 the CNEN appointed its Division of Radiological Protection (DRP) to establish a new Radiation Surveillance network. This network consists of 17 stations (see figure 3), twelve of which are located at airports and operated by airline personnel. The remaining five stations are located at Mexico City, Mérida, Veracruz, San Luis Potosí and Ensenada. Staff members of the DRP operate the station at Mexico City while the other four stations are manned by members of the Centro de Previsión del Golfo de México, the Chemistry Department of the University of Merída, the Institute de

Zonas desérticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air for 24 hours a day, 3 or 4 days a week at the rate of approximately 1,200 cubic meters per day, through a high-efficiency, 6 x 8-inch glass fiber filter, using high volume samplers. After each 24-hour sampling period, the filter is removed and forwarded via air mail to the "Laboratorio de Estudios sobre Contaminación Radiactiva", CNEN, in Mexico City for assay of gross beta activity. A minimum of 3 or 4 days after collection is allowed for decay of radon and thoron daughter natural radioactivity. Data are not extrapolated to time of collection.

Results

The maximum, minimum and average fission product beta concentrations in surface air during August 1964 are presented in table 3. The data are also represented in the beta activity isogram map of North America, figure 4.

TABLE 3.—GROSS BETA ACTIVITY OF AIRBORNE PARTICULATES, MEXICO, AUGUST 1964

[Concentrations in pc/m³]

Station	Number of Samples	Maximum	Minimum	Average
Acapulco	8	0.3	0.1	0.1
Ciudad Juárez	22	1.3	0.1	0.2
Chihuahua	22	1.3	0.1	0.3
Ensenada	4	0.5	0.4	—
Guadalajara	16	0.2	0.1	0.1
Guaymas	11	0.2	0.1	0.1
La Paz	17	0.5	0.1	0.2
Matamoros	15	0.5	0.1	0.2
Mazatlán	5	0.1	0.1	0.1
Mérida	6	0.3	0.1	0.2
México, D.F.	15	0.1	0.1	0.1
Nuevo Laredo	10	0.3	0.1	0.2
San Luis Potosí	5	0.5	0.1	0.2
Tampico	22	0.3	0.1	0.2
Torreón	26	0.4	0.1	0.2
Tuxtla Gutiérrez [a]				
Veracruz	16	0.5	0.1	0.2

[a] Temporarily shut down.

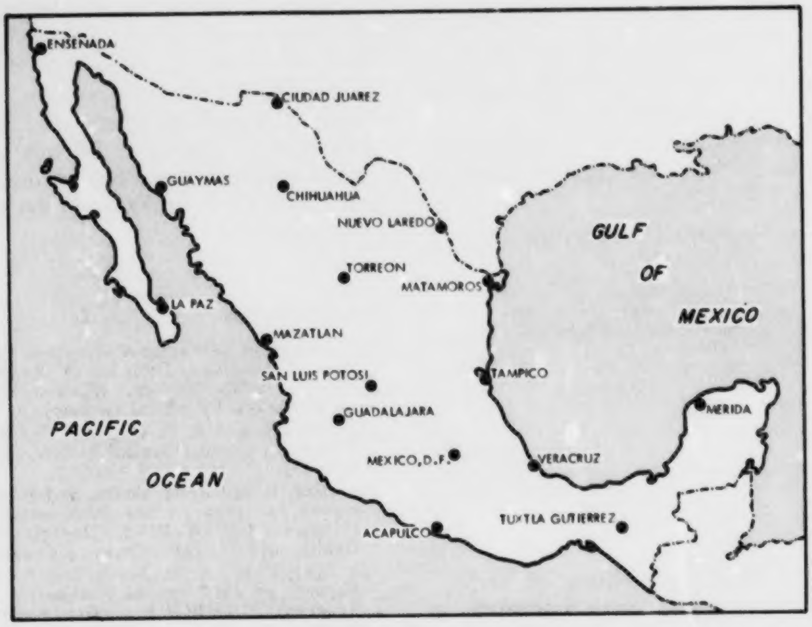
ENSENADA
CIUDAD JUAREZ
GUAYMAS
CHIHUAHUA
NUEVO LAREDO
TORREON
MATAMOROS
GULF
OF
MEXICO
LA PAZ
MAZATLAN
SAN LUIS POTOSI
TAMPICO
MERIDA
GUADALAJARA
PACIFIC
MEXICO, D.F.
VERACRUZ
OCEAN
TUXTLA GUTIERREZ
ACAPULCO

FIGURE 4.—FALLOUT NETWORK SAMPLING STATIONS IN MEXICO

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4. Pan American Air Sampling Program August 1964

Pan American Health Organization and Public Health Service

Gross beta activity in air is monitored by four countries in the Americas under the auspices of a collaborative program developed by the Pan American Health Organization and the Public Health Service (PHS) for assisting countries of the Americas in developing radiological health programs. The sampling equipment and analytical services are provided by the Division of Radiological Health, PHS, and are identical with those employed for the Radiation Surveillance Network.

The four air sampling stations included in the program are operated by the technical staff of the Ministry of Health in each country. The station in Kingston, Jamica, is operated by the Public General Hospital; in Caracas, Venezuela, by the Venezuelan Institute for Scientific Investigations; in Lima, Peru, by the Institute of Occupational Health; and in Santiago, Chile, by the Occupational Health Service. The Kingston station began operation in March 1964, and the other three were started near the end of 1962.

The August 1964 air monitoring results from the four participating countries are given in table 4. The Caracas and Jamaica stations, included in figure 5 with the August averages adjusted by the RSN intercalibration factor,[3] were used in positioning the beta concentration isograms.

TABLE 4.—GROSS BETA ACTIVITY IN AIR, AUGUST 1964

[Concentrations in pc/m³]

Sampling stations	No. of samples	Maximum	Minimum	Average [a]
Kingston, Jamaica	14	0.60	<0.10	0.25
Caracas, Venezuela	21	0.19		0.11
Lima, Peru	21	0.17		0.10
Santiago, Chile	27	0.27		0.14

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes. If the <0.10 values represent more than 10 percent of the average, a less-than sign is placed in front of the average.

5. Gross Beta Activity in Air, North America August 1964

Beginning with January 1963 data, monthly average concentrations of airborne gross beta activity in Canada and the United States have been presented in combined form as isogram maps of most of North America. The data from the Radiation Surveillance Network and the Canadian Air Network were adjusted to each other by means of an intercalibration factor derived by Lockhart and Patterson (*13*).

With the formation of the Mexican Air monitoring program, new intercalibration ratios were determined, this time including the Canadian Network, Radiation Surveillance Network, National Air Sampling Network, the HASL 80th Meridian Network, and the Mexican Network (*14*). The new intercalibration factors reflect some changes in standardization in both the RSN and the Canadian Air Network, effective September 1963.

Figure 5 shows the August 1964 activity in air throughout North America based on the data from the Canadian Air Monitoring Program, the Radiation Surveillance Network and Mexican Air Monitoring program. An intercalibration factor of 1.28 was applied to the RSN data and the Mexican data were multiplied by 0.81 in order to adjust them to Canadian data.

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[3] The RSN factor is 1.28.

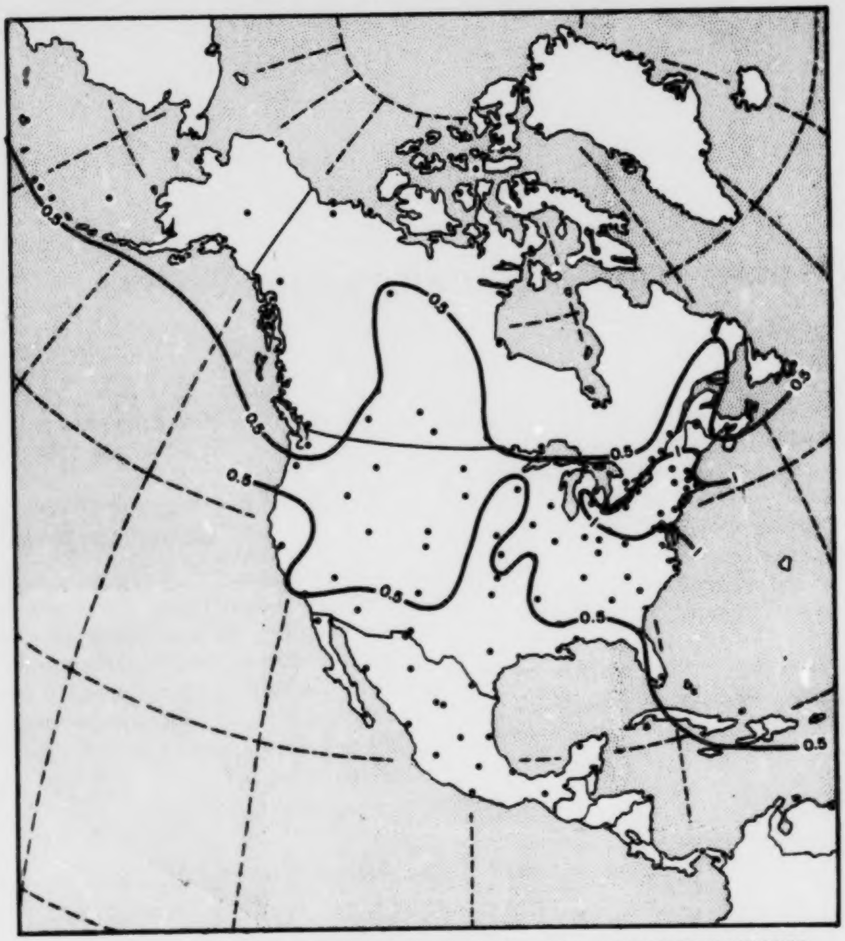

FIGURE 5.—ISOGRAM OF AVERAGE GROSS BETA CONCENTRATIONS IN AIR, NORTH AMERICA, AUGUST 1964

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MONTHLY DEPOSITION OF VARIOUS RADIONUCLIDES

For the purpose of this section the word "fallout" refers to the deposition of radioactive materials on the earth's surface, normally expressed in terms of the activity of selected radionuclides deposited on a unit surface during a given period of time. Unless otherwise stated, fallout measurements include both precipitation and dry fallout (settled dust).

Following are reports of fallout measurements at selected stations in Canada.

Fallout Measurements in Canada April–June 1964

Department of National Health and Welfare
Ottawa, Canada

The monthly accumulated precipitation samples collected in conjunction with the Canadian air sampling network described earlier in this issue represent total fallout (wet and dry), since they are collected in deep pots lined with polyethylene. The radiochemical analyses of these samples for April through June 1964 are given in table 1.

TABLE 1.—ANALYSIS OF FALLOUT FOR SPECIFIC RADIONUCLIDES, APRIL–JUNE 1964

[Deposition in nc/m²]

Station	April		May		June	
	Sr^{90}	Cs^{137}	Sr^{90}	Cs^{137}	Sr^{90}	Cs^{137}
Calgary	0.27	0.65	2.17	3.65	1.63	3.00
Coral Harbour	0.10	0.25	0.21	0.34	0.94	2.03
Edmonton	0.82	1.50	4.36	6.72	1.01	2.46
Ft. Churchill	0.32	0.46	1.34	1.80	1.39	2.22
Ft. William	3.85	5.55	5.84	9.65	5.10	8.05
Fredericton	1.95	3.30	0.29	1.42	1.84	4.41
Goose Bay	0.77	0.83	2.12	3.12	2.87	5.53
Halifax	1.75	3.36	1.36	2.28	1.63	2.79
Inuvik	0.10	0.20	0.24	0.41	1.76	2.06
Montreal	1.32	2.20	1.65	3.11	1.26	2.11
Moosonee	0.97	2.35	4.31	6.72	2.64	5.04
Ottawa	1.71	2.02	2.10	3.63	0.98	1.62
Quebec	1.50	2.48	1.46	3.46	2.66	5.17
Regina	0.36	0.76	1.54	2.54	2.87	5.38
Resolute	0.52	0.52	1.14	1.70	0.63	0.92
St. John's, Nfld	1.17	2.11	2.00	3.35	2.34	3.61
Saskatoon			1.74	3.19	1.57	2.80
Sault Ste. Marie	2.24	3.18	2.38	3.89	2.09	3.28
Toronto			1.70	3.10	0.61	1.02
Vancouver	1.11	1.91	3.05	4.66	1.49	2.25
Whitehorse	0.10	0.23	0.40	1.16	0.21	1.30
Windsor	2.76	5.20	1.11	2.03	2.96	5.16
Winnipeg	1.05	2.00	1.91	3.90	2.93	4.44
Yellowknife	0.18	0.31	0.70	1.24	0.59	1.10

Section II—Milk and Food

MILK SURVEILLANCE

Although milk is only one of the many sources of dietary intake of radionuclides, it is the single food item most often used as an indicator of the population's intake of radionuclides from the environment. This is because fresh milk is consumed by a large segment of the United States population and contains most of the radionuclides occurring in the environment which have been identified as biologically important. In addition, milk is produced and consumed on a regular basis, is convenient to handle, is easily analyzed, and samples which are representative of milk consumption in any area can be readily obtained.

1. Pasteurized Milk Network, August 1964

Division of Radiological Health and Division of Environmental Engineering and Food Protection, Public Health Service

The Public Health Service pasteurized milk surveillance program had its origin in a raw milk monitoring network (*1*) established by the Service in 1957. One of the primary objectives of the raw milk network was the development of methods for milk collection and radiochemical analysis suitable for larger scale programs.

Experience derived from this earlier network led to the activation of a pasteurized milk sampling program with stations selected to provide nationwide surveillance of milk production and consumption areas. The present network, which consists of 63 stations, has at least one station in every State, the Canal Zone, and Puerto Rico.

Sampling Procedure

Through the cooperation of State and local milk sanitation authorities, samples are routinely collected at each station. The method specifies that an individual station's sample be composited of subsamples from each milk processing plant in proportion to the plant's average sales in the community served. At most stations the sample represents from 80 to 100 percent of the milk processed. Prior to September 15, 1961, the composite sample was taken from one day's sales per month and was as representative of the community's supply as could be achieved under practical conditions. Beginning with the resumption of nuclear weapons testing in the atmosphere in September 1961, and continuing through January 1963, samples were collected twice a week at nearly all stations and daily for short periods at selected stations. Since then, the sampling frequency has been reduced to once a month.

Samples are preserved with formaldehyde and are sent to the PHS Southwestern (SWRHL), Southeastern (SERHL), or Northeastern Radiological Health Laboratories (NERHL) for analysis. Gamma analyses for iodine-131 are made within 3 to 6 days after sample collection, and any results exceeding 100 pc/liter are immediately telephoned to State health officials for possible public health action. Analytical results are normally available 6 to 7 weeks after monthly samples are received by the laboratories; publication in *RHD* follows 3 to 4 months after the monthly samples are composited for analyses.

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Analytical Procedures

Iodine–131, cesium–137, and barium–140 concentrations are determined by gamma scintillation spectroscopy.[1] After the weekly samples are gamma scanned, samples from two consecutive weeks are composited and analyzed radiochemically for strontium–89 and strontium–90. There is an inherent statistical variation associated with all measurements of radionuclide concentrations. With the low radionuclide levels which are usually found in milk and other environmental samples, this variation on a percentage basis is relatively high. The variation depends upon such factors as the method of chemical analysis, the sample counting rate and counting time, interferences from other radionuclide and the background count. For milk samples, counting times of 50 minutes for gamma spectroscopy and 30 to 50 minutes for beta determinations are used. Table 1 shows the approximate total analytical error (including counting error) associated with radionuclide concentrations in milk. These errors were determined by comparing results of a large number of replicate analyses. Table 1 gives the 95 percent confidence limits between which the true concentrations of the selected radionuclides might be expected in the analyses. The minimum detectable concentration is defined as the measured concentration at which the two-standard-deviation analytical error is equal to the measurement. Accordingly, the minimum detectable concentrations in units of pc/liter are Sr^{89}, 5; Sr^{90}, 2; Cs^{137}, 10; Ba^{140}, 10; and I^{131}, 10. At these levels and below, the counting error comprises nearly all of the analytical error.

TABLE 1.—ANALYTICAL ERRORS ASSOCIATED WITH ESTIMATED CONCENTRATIONS FOR SELECTED RADIONUCLIDES IN MILK

Nuclide	Estimated concentration (pc/liter)	Error [a] (pc/liter)	Estimated concentration (pc/liter)	Error [a] (percent of concentration)
Iodine-131	0 to 100	±10	100 or greater	±10
Barium-140	0 to 100	±10	100 or greater	±10
Cesium-137	0 to 100	±10	100 or greater	±10
Strontium-89	0 to 50	±5	50 or greater	±10
Strontium-90	0 to 20	±2	20 or greater	±10

[a] Two standard deviations (2σ).

Calcium analyses at SERHL are done by an ion exchange and permanganate titration method while at NERHL and SWRHL an ethylenediaminetetraacetic acid (EDTA) method is used. Stable potassium concentrations are estimated from the potassium–40 concentrations[2] determined from the gamma spectrum.

Data Presentation

Table 2 presents summaries of the analyses for August 1964 (July 26-August 29). Although not shown in table 2, the iodine–131 and barium–140 monthly average concentrations in milk were less than 10 pc/liter. Radionuclide values reported by a laboratory as being below the minimum detectable concentration have been averaged by using one-half the minimum detectable value. The averaging procedure was modified for iodine–131 and barium–140 in October 1963 when nondetectable concentrations of these radionuclides were considered zero. A similar procedure is used for the network average.

Figures 1 and 2 are isogram maps showing the estimated strontium–90 and cesium–137 concentrations in milk over the entire country. The value printed beside each station is the monthly average concentration for that station. The isograms were developed by arbitrary interpolation between values for the individual stations. Additional modifications to the isograms are made according to available information on milksheds.

In order to develop the distribution of the network's stations *versus* radionuclide concentrations in milk, tables 3 and 4 have been prepared using monthly averages.

The average monthly strontium–90 concentrations in pasteurized milk from selected cities in the sampling program are presented in figure 3. The data regarding reported nuclear detonations given in this figure are presented for information only. The underground nuclear detonations during 1963 and 1964 are not intended to imply a cause and effect relationship with the rising strontium levels during this period. Each graph shows the strontium–90 concentrations in milk from one city in each of the four U.S. Bureau of Census regions. This method of selection permits graphic presentation of data for each city in the network three

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[1] Southeastern Radiological Health Laboratory employs a radiochemical procedure for barium–140 analysis.

[2] The conversion factor is 1.18 x 10^{-3} g K/pc K^{40}.

TABLE 2.—STABLE ELEMENT AND RADIONUCLIDE CONCENTRATIONS IN PASTEURIZED MILK, AUGUST 1964 [a]

[Average radioactivity concentrations in pc/liter]

Sampling locations		Calcium (g/liter)		Potassium (g/liter)		Strontium-89		Strontium-90		Cesium-137		Last Sr^{90} graph in *RHD* (1964)
		Second quarter	Avg. for month	Second quarter	Avg. for month	Second quarter	Avg. for month	Second quarter	Avg. for month	Second quarter	Avg. for month	
Ala:	Montgomery	1.15	1.17	1.5	1.4	<5	<5	26	22	90	70	Oct
Alaska:	Palmer	1.22	1.17	1.4	1.4	5	<5	25	13	150	100	Nov
Ariz:	Phoenix	1.17	1.14	1.5	1.3	<5	<5	6	4	30	25	Sep
Ark:	Little Rock	1.15	1.14	1.5	1.6	<5	<5	58	39	160	80	Nov
Calif:	Sacramento	1.24	1.27	1.5	1.3	<5	<5	9	5	50	25	Dec
	San Francisco	1.22	1.18	1.4	1.3	<5	<5	12	9	55	30	Oct
Canal Zone:	Cristobal	1.09	1.11	1.5	1.6	<5	<5	6	4	55	50	Nov
Colo:	Denver	1.22	1.25	1.5	1.4	<5	5	22	17	90	100	Dec
Conn:	Hartford	1.14	1.11	1.5	1.6	<5	<5	23	20	160	115	Dec
Del:	Wilmington	1.20	1.12	1.5	1.5	<5	<5	30	19	145	85	Sep
D. C:	Washington	1.12	1.12	1.6	1.6	<5	<5	23	18	100	60	Oct
Fla:	Tampa	1.13	1.18	1.5	1.5	<5	<5	15	15	260	255	Sep
Ga:	Atlanta	1.15	1.16	1.5	1.5	<5	<5	36	29	165	105	Oct
Hawaii:	Honolulu	1.16	1.19	1.6	1.3	<5	<5	11	15	85	75	Nov
Idaho:	Idaho Falls	1.21	1.22	1.4	1.2	10	<5	34	26	205	105	Sep
Ill:	Chicago	1.16	1.11	1.5	1.5	<5	<5	19	20	130	85	Oct
Ind:	Indianapolis	1.20	1.17	1.5	1.5	<5	<5	25	16	110	65	Dec
Iowa:	Des Moines	1.22	1.20	1.4	1.3	5	<5	30	20	100	65	Sep
Kans:	Wichita	1.19	1.17	1.4	1.3	5	<5	25	16	80	50	Nov
Ky:	Louisville	1.13	1.12	1.5	1.6	<5	<5	37	27	100	50	Sep
La:	New Orleans	1.18	1.19	1.5	1.6	<5	<5	59	49	180	115	Nov
Maine:	Portland	1.18	1.15	1.5	1.5	<5	<5	33	26	210	180	Sep
Md:	Baltimore	1.13	1.12	1.5	1.5	<5	<5	28	20	125	60	Sep
Mass:	Boston	1.18	1.14	1.6	1.5	<5	<5	38	30	245	195	Oct
Mich:	Detroit	1.17	1.12	1.5	1.5	<5	<5	21	15	120	90	Dec
	Grand Rapids	1.22	1.16	1.5	1.5	<5	<5	23	18	135	100	Sep
Minn:	Minneapolis	1.22	1.21	1.5	1.4	10	<5	37	26	160	110	Oct
Miss:	Jackson	1.22	1.19	1.5	1.5	<5	<5	53	38	125	90	Dec
Mo:	Kansas City	1.19	1.16	1.4	1.3	10	<5	32	24	100	50	Dec
	St. Louis	1.21	1.22	1.4	1.3	10	<5	28	17	95	55	Nov
Mont:	Helena	1.19	1.22	1.5	1.5	5	<5	32	19	195	100	Nov
Nebr:	Omaha	1.21	1.24	1.5	1.4	5	<5	30	22	105	75	Sep
Nev:	Las Vegas	1.20	1.18	1.5	1.3	<5	<5	10	7	90	50	Oct
N. H:	Manchester	1.19	1.15	1.5	1.5	<5	<5	33	28	250	200	Sep
N. J:	Trenton	1.16	1.11	1.5	1.5	<5	<5	23	16	135	90	Dec
N. Mex:	Albuquerque	1.19	1.19	1.5	1.4	5	<5	14	7	70	45	Nov
N. Y:	Buffalo	1.15	1.08	1.5	1.5	<5	<5	24	17	160	105	Dec
	New York	1.14	1.11	1.5	1.5	<5	<5	30	23	180	120	Oct
	Syracuse	1.16	1.12	1.6	1.5	<5	<5	23	15	160	85	Nov
N. C:	Charlotte	1.16	1.16	1.5	1.5	<5	<5	43	39	140	105	Nov
N. Dak:	Minot	1.20	1.23	1.5	1.4	15	10	72	44	175	125	Sep
Ohio:	Cincinnati	1.18	1.16	1.5	1.5	<5	<5	28	17	105	60	Dec
	Cleveland	1.18	1.12	1.5	1.5	<5	<5	25	18	135	80	Nov
Okla:	Oklahoma City	1.13	1.12	1.6	1.6	<5	<5	27	18	75	50	Oct
Ore:	Portland	1.26	1.24	1.4	1.4	10	<5	40	28	190	175	Dec
Pa:	Philadelphia	1.17	1.11	1.5	1.5	<5	<5	25	17	140	75	Nov
	Pittsburgh	1.18	1.12	1.5	1.5	<5	<5	34	29	175	115	Nov
P. R:	San Juan	1.11	1.14	1.5	1.7	<5	<5	15	10	90	70	Nov
R. I:	Providence	1.17	1.13	1.5	1.5	<5	<5	27	21	180	140	Sep
S. C:	Charleston	1.16	1.16	1.5	1.6	<5	<5	35	34	145	120	Dec
S. Dak:	Rapid City	1.14	1.24	1.5	1.3	10	<5	48	40	155	105	Oct
Tenn:	Chattanooga	1.17	1.22	1.4	1.5	<5	<5	51	40	145	95	Oct
	Memphis	1.16	1.18	1.5	1.6	<5	<5	42	31	85	55	Sep
Tex:	Austin	1.11	1.12	1.6	1.6	<5	<5	10	8	45	30	Oct
	Dallas	1.12	1.16	1.5	1.6	<5	<5	22	17	70	45	Dec
Utah:	Salt Lake City	1.24	1.31	1.5	1.5	10	<5	30	23	195	175	Nov
Vt:	Burlington	1.18	1.10	1.5	1.5	<5	<5	30	25	190	155	Dec
Va:	Norfolk	1.13	1.13	1.5	1.5	<5	<5	28	24	110	70	Dec
Wash:	Seattle	1.21	1.24	1.5	1.3	10	<5	36	28	190	170	Oct
	Spokane	1.27	1.24	1.5	1.4	10	<5	29	24	155	130	Dec
W. Va:	Charleston	1.13	1.14	1.5	1.4	<5	<5	34	24	95	55	Oct
Wis:	Milwaukee	1.23	1.18	1.6	1.6	<5	<5	21	14	145	90	Sep
Wyo:	Laramie	1.22	1.16	1.4	1.3	15	<5	25	18	120	105	Sep
Network average		1.18	1.17	1.5	1.5	<5	<5	28.9	21.6	133	94	Nov

[a] The monthly average iodine-131 and barium-140 concentration at each station was <10 pc/liter.

times a year. The last column in table 2 shows the most recent issue in which a graph of the strontium-90 concentration was given for each station. A tabulation of the network monthly maximum, minimum, and average radionuclide concentrations in milk was given for March 1960—March 1964 in the July 1964 issue of *RHD* (2).

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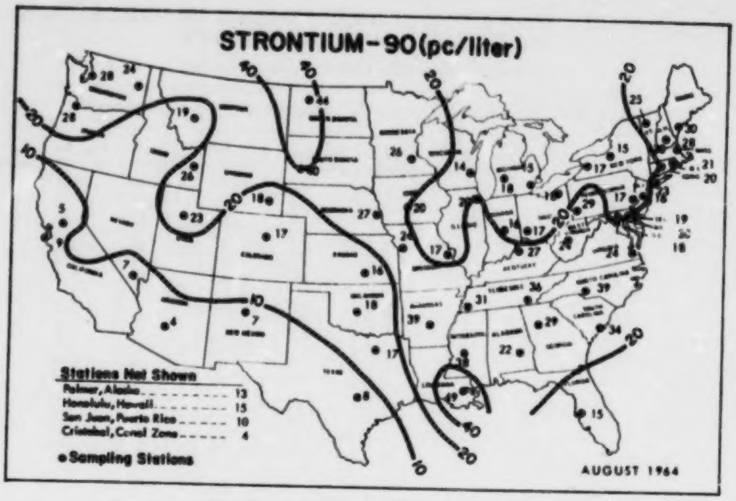
STRONTIUM-90(pc/liter)
Stations Not Shown
Palmer, Alaska 13
Honolulu, Hawaii 15
San Juan, Puerto Rico 10
Cristobal, Canal Zone 4
● Sampling Stations
AUGUST 1964

FIGURE 1.—STRONTIUM-90 CONCENTRATIONS IN PASTEURIZED MILK

TABLE 3.—STATION MONTHLY AVERAGES FOR STRONTIUM-90 MARCH-AUGUST 1964

Range (pc/liter)	Number of stations in range (1964)					
	Mar.	Apr.	May	June	July	Aug.
Under 10	2	4	3	4	6	7
10–19	17	12	[illegible]	6	6	23
20–29	30	28	[illegible]	23	29	23
30–39	10	12	[illegible]	17	14	6
40–49	2	2	6	10	4	4
50–59	1	2	4	2	1	0
60–69	1	3	1	0	2	0
70–79	0	0	1	1	0	0

TABLE 4.—STATION MONTHLY AVERAGES FOR CESIUM-137 MARCH-AUGUST 1964

Range (pc/liter)	Number of stations in range (1964)					
	Mar.	Apr.	May	June	July	Aug.
Under 50	2	2	2	1	4	6
50–99	11	12	16	19	24	30
100–149	22	23	17	24	21	19
150–199	20	17	23	13	8	6
200–249	6	7	3	4	3	1
250–299	2	2	2	2	2	1
300–349	0	0	0	0	0	0
350–399	0	0	0	0	0	0

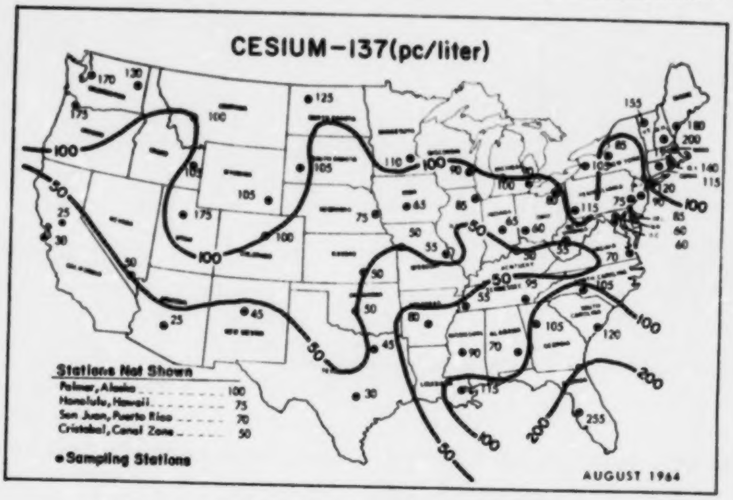
CESIUM-137(pc/liter)
Stations Not Shown
Palmer, Alaska 100
Honolulu, Hawaii 75
San Juan, Puerto Rico 70
Cristobal, Canal Zone 50
● Sampling Stations
AUGUST 1964

FIGURE 2.—CESIUM-137 CONCENTRATIONS IN PASTEURIZED MILK

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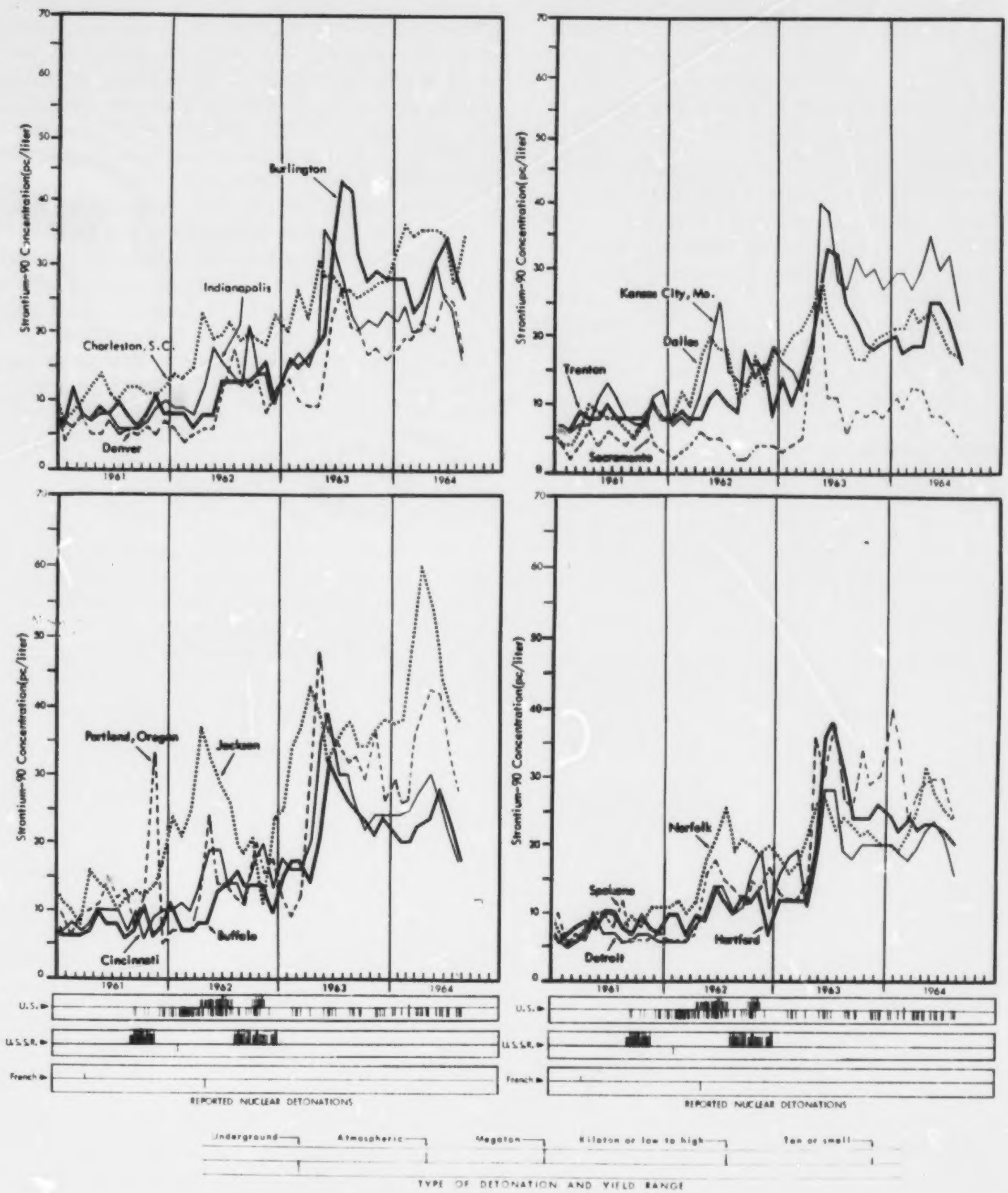

FIGURE 3.—STRONTIUM-90 IN PASTEURIZED MILK, 1961—AUGUST 1964

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2. California Milk Network[3]
April-June 1964

State of California
Department of Public Health

Surveillance of specific radionuclides in milk is one phase of California's Department of Public Health program of radiation control. This milk monitoring function has been conducted at 8 milksheds since January 1960 by the Department's Bureau of Radiological Health, a constituent of the Division of Environmental Sanitation. Since the addition of the Del Norte and Mendocino milksheds to the program in March 1962, sampling of pasteurized milk weekly or biweekly has been conducted at 10 major milksheds (see figure 4). The original sampling locations were chosen by the State Department of Agriculture as being representative of milk consumed by a high percentage of the population of the State.

Analytical Procedures

After precipitation of the proteins with trichloroacetic acid, yttrium–90 is separated and beta counted, and total radiostrontium remaining in the filtrate is determined by beta counting in a low background counter, usually for a 60-minute period. Strontium–90 is determined from the yttrium–90 results; strontium–89 is determined by difference.

Potassium–40, iodine–131, cesium–137 and barium–140 in whole fluid milk are determined by gamma scintillation spectroscopy using a sodium-iodide crystal. A normal counting time of 100 minutes is used. The stable potassium content of milk (g/liter) may be estimated by multiplying the potassium–40 concentration (pc/liter) by 1.18 x 10^{-3}. A more complete description of the laboratory equipment and procedures has been published in the February 1963 issue of *Radiological Health Data* (*3*).

Results

The monthly averages of the radionuclide and calicum data for milk for the period April-June 1964 are presented in table 5. Background information of the differences among the California milksheds was presented by Heslep and Cornish in the December 1963 issue of *RHD* (*4*).

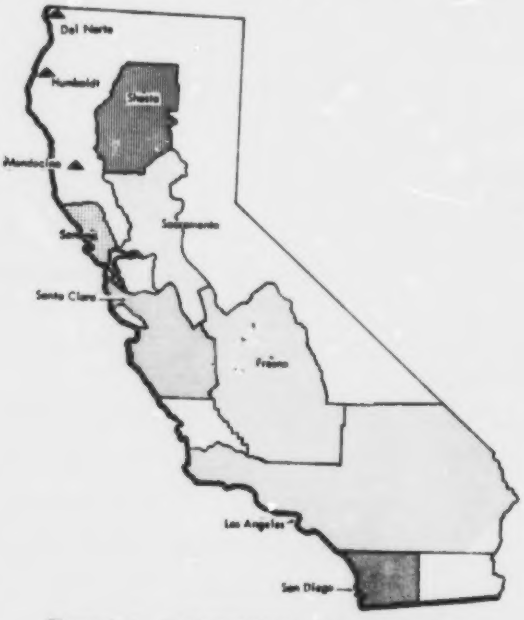

FIGURE 4.—CALIFORNIA MILKSHEDS

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[3] Data from *Radiological Health News Vol. 3*, No. 4, Bureau of Radiological Health, State of California Department of Public Health, 2151 Berkeley Way, Berkeley 4, California.

TABLE 5.—RADIONUCLIDES IN CALIFORNIA MILK, APRIL–JUNE 1964 [a]

[Radioactivity concentrations in pc/liter]

Element and month	Del Norte	Fresno	Humboldt	Los Angeles	Mendocino	Sacramento	San Diego	Santa Clara	Shasta	Sonoma	Average
Calcium (g/liter)											
April	1.36	1.19	1.05	1.16	1.25	1.18	1.20	1.17	1.18	1.24	1.20
May	1.48	1.18	1.26	1.11	1.21	1.21	1.16	1.22	1.18	1.23	1.22
June	1.34	1.18	1.23	1.08	1.15	1.11	1.12	1.16	1.12	1.16	1.17
Potassium-40											
April	1,290	1,255	1,090	1,255	1,275	1,300	1,230	1,320	1,265	1,265	1,255
May	1,290	1,230	1,156	1,235	1,265	1,233	1,250	1,310	1,165	1,270	1,242
June	1,260	1,260	1,180	1,220	1,350	1,280	1,235	1,270	1,235	1,260	1,255
Strontium-89											
April	3.3	0.8	4.0	0.4	2.7	0.9	[b] 0	1.4	2.8	2.8	1.9
May	[b] 0	0	0	0	0	0.8	0	0.3	5.5	0	0.7
June	14.0	0	0	0	0	0	0	0	0	0	1.4
Strontium-90											
April	115.8	6.3	27.5	6.8	15.3	12.4	5.4	4.5	12.8	10.9	21.8
May	77.6	5.0	22.8	4.1	17.2	8.3	7.1	5.9	10.6	9.4	16.8
June	60.9	10.2	17.6	4.2	11.3	11.1	5.3	7.0	10.7	9.8	14.8
Cesium-137											
April	189	40.2	72.2	38.1	38.1	43.6	24.0	37.5	63.9	40.2	58.7
May	166	37.8	50.0	41.6	30.4	38.2	31.3	39.5	46.7	33.0	52.4
June	206	37.8	78.9	33.1	30.0	49.9	19.7	42.4	59.5	40.2	59.8

[a] No significant amounts of iodine-131 or barium-lanthanum-140 in samples for this period were found.
[b] A zero indicates activity less than twice the counting error at the 95 percent confidence level.

3. Florida Milk Network
January-March 1964

Division of Radiological and
Occupational Health
Florida State Board of Health

The Florida State Board of Health began sampling raw milk for iodine-131 analysis in two major areas of the State in November 1962. The program has since been expanded to include the analysis of milk for strontium-89, strontium-90 and cesium-137. Raw milk samples are received from the six areas shown in figure 5. Samples for iodine-131 analysis are taken from a tank truck, the route of which passes by farms widely dispersed over the area represented. Where there is no route representative of a large portion of the area, samples are collected from selected farms and combined. Samples were collected weekly when iodine-131 was detectable in milk. Presently, the sampling is on a monthly basis.

A regional State Board of Health Laboratory is located in each of these areas shown in figure 5. For strontium-89, strontium-90 and cesium-137 analysis monthly composite raw milk samples are prepared by each regional laboratory from samples routinely submitted. The composite sample is a size-stratified randon sample obtained by numbering farms and using a table of random numbers. Each size stratum contributes to the total volume of the sample in proportion to the number of cows in that stratum. Ten percent of the farms in each stratum is selected for compositing. These composite samples are then sent to the State Radiological Health Laboratory in Orlando for analysis.

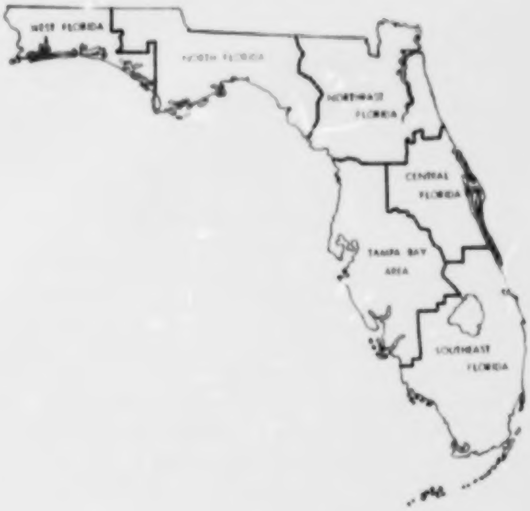

FIGURE 5.—FLORIDA MILK SAMPLING LOCATIONS

TABLE 6.—RADIONUCLIDES IN FLORIDA MILK, JANUARY-MARCH 1964[a]

[Concentrations in pc/liter]

Sampling location	Strontium-89			Strontium-90			Cesium-137		
	Jan.	Feb.	Mar.	Jan.	Feb.	Mar.	Jan.	Feb.	Mar.
West	<5	5	<5	17	10	13	191	192	232
North	<5	<5	<5	16	11	14	170	203	175
Northeast	<5	<5	<5	15	10	11	159	196	181
Central	<5	<5	<5	10	11	12	211	244	309
Tampa Bay Area	<5	<5	<5	8	13	10	176	198	234
Southeast	<5	<5	<5	12	10	15	201	200	234
Average	<5	<5	<5	13	11	13	185	206	228

[a] All iodine-131 concentrations during this period were <2 pc/liter.

Milk produced in the counties comprising each area is generally processed, marketed, and consumed in that area. These areas are characterized by differences in dairying practices related to the gradual transition from small farms—using locally grown feeds in the "West Florida" region—to larger farms using different types of grass and predominantly purchased feeds in the southern areas.

Analytical Procedures

Strontium-89 and strontium-90 concentrations in milk samples are determined by radiochemical separations and beta counting in a low background counter. Cesium-137 and iodine-131 content is determined by gamma scanning with a 512-channel analyzer.

Results and Discussion

Table 6 presents all available monthly average strontium-90, strontium-89, and cesium-137 concentrations in Florida milk for January-March 1964. Iodine-131 results for 1963 appeared in the March 1964 issue of *RHD* (*5*).

Comparison of the Public Health Service Pasteurized Milk Network data for Tampa, Florida, for 1963 (May 1963-April 1964 issues of *RHD*) with the results from the Florida State Board of Health's Tampa Bay Area gives an indication of the agreement of the two sampling methods:

1. raw milk composites from a sampling of farms and
2. pasteurized milk composites from processing plants.

These two sampling techniques provide estimates of the yearly average strontium-90 concentrations in raw and pasteurized milk that are within 38 percent of each other. Yearly average strontium-89 concentrations in raw and pasteurized milk have been within 14 percent of each other. For cesium-137 concentrations, the two methods gave average results within 15 percent of each other for April-December 1963 when analyses were being done.

4. Indiana Milk Network
August 1964

Bureau of Environmental Sanitation
Indiana State Board of Health

The Indiana State Board of Health began sampling pasteurized milk for radiological analysis in September 1961. Indiana was geographically divided into five major milksheds, and one large dairy within each milkshed was selected as a sampling station (figure 6).

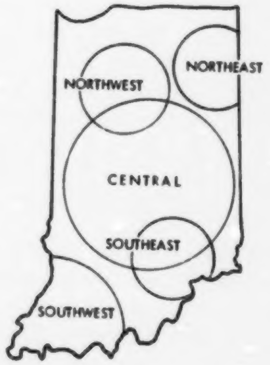

FIGURE 6.—INDIANA MILK SAMPLING LOCATIONS

The milk samples are routinely analyzed for iodine–131, cesium–137, barium–140, strontium–89 and strontium–90. Until August 1963, analyses for the gamma emitters iodine–131, cesium–137 and barium–140 were conducted on a weekly basis, except when iodine–131 exceeded 100 pc/liter, at which times the frequency of sampling was increased. Because of continued low concentrations of the short-lived gamma emitters, the sampling frequency was reduced in August 1963 to once per month for the northeast, southeast and southwest milksheds. Strontium–89 and strontium–90 analyses are performed monthly for each station.

An ion exchange analytical procedure (*6*) is employed for strontium–89 and strontium–90 analyses. Minimum detectable levels for strontium–89 and strontium–90 are about 5 and 1 pc/liter, respectively. A 512-channel pulse height analyzer and shielded 4 x 4-inch sodium iodide crystal are used for the gamma analysis of iodine–131, cesium–137, and barium–140. Analyses of counting statistics indicate that the lower limit of detectability for both iodine–131 and barium–140 is 5 pc/liter. Cesium–137 analyses are subject to a 6 percent error at the 100 pc/liter level. Additional factors such as drift of the analyzer and calibration factors will increase these limits to some extent.

The monthly averages of the data obtained for the individual sampling stations and the State averages are reported in table 7.

TABLE 7.—RADIONUCLIDES IN INDIANA MILK, AUGUST 1964 [a]

[Radionuclide concentrations in pc/liter]

Sampling location	Calcium (g/liter)	Potassium-40	Strontium-90	Cesium-137
Northeast	1.20	1,280	16	70
Southeast	1.20	1,310	16	55
Central	1.20	1,330	17	60
Southwest	1.18	1,290	19	50
Northwest	1.18	1,310	15	75
State average	1.19	1,300	17	60

[a] The monthly average iodine-131, barium-140, and strontium-89 concentrations at each station were zero.

5. New York Milk Network
June 1964

Division of Environmental Health Services
State of New York Department of Health

Milk samples collected routinely from six cities—Albany, Buffalo, Massena, Newburgh, New York City, and Syracuse (figure 7) are analyzed for their radionuclide content by the State of New York Department of Health. Pasteurized milk samples are collected daily and composited weekly for the determination of strontium–89, strontium–90, iodine–131, cesium–137 and barium-lanthanum–140 at all stations except Massena, where samples are composited bi-weekly, and at New York City where one daily milk sample representing the total milk supply for that day is obtained and analyzed once per week. Samples are obtained from processing plants except at Albany, where the daily sample is obtained from a marketing point. During periods when cows are no longer on stored feed, the sample from Albany is analyzed daily for iodine–131. In the event that any city reports iodine–131 concentrations exceeding 100 pc/liter, increased surveillance is undertaken.

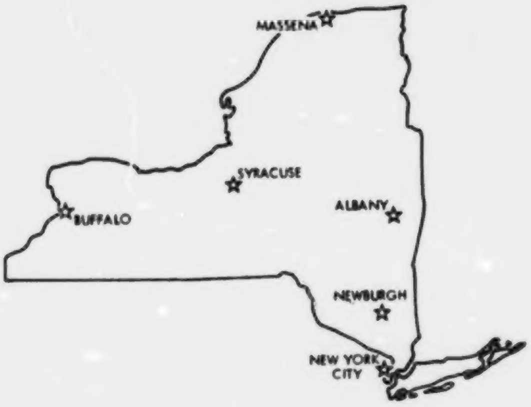

FIGURE 7.—NEW YORK MILK SAMPLING LOCATIONS

A matrix method (*7*) is used for the analysis of spectral data to determine the concentrations of gamma-emitting nuclides in milk. With this method, the individual nuclide contributions to the gamma spectrum are separated by solution of simultaneous equations describing the spectral interferences.

The analytical procedure for strontium-89 and strontium-90 is based on ion exchange methods. Cations (including radiostrontium) are eluted from the ion exchange resin with sodium chloride solution, strontium isotopes are gathered by means of sodium carbonate, isolated by means of ethylenediaminetetraacetic acid (EDTA), and radiostrontium is counted with a low background beta counter having an 0.8 mg/cm² window. The strontium-90 portion is differentially estimated by a second count 40 hours later to determine the rate of in-growth of its daughter product yttrium-90. The monthly average radionuclide concentrations in milk are shown in table 8.

Table 8.—RADIONUCLIDES IN NEW YORK MILK, JUNE 1964 [a]

[Average concentrations in pc/liter]

Sampling location	Strontium-89	Strontium-90	Cesium-137
Albany	<3	20	86
Buffalo	3	20	103
Massena	<3	33	198
Newburgh	5	26	111
New York City	<3	28	129
Syracuse	4	19	89
Average	3	24	119

[a] The monthly average I^{131} and $Ba\text{-}La^{140}$ (in equilibrium) at each station were less than the minimum detectable levels (20 pc/liter).

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6. Canadian Milk Network,[3] August 1964

Radiation Protection Division
Department of National Health and Welfare,
Ottawa, Canada

The Radiation Protection Division of the Department of National Health and Welfare began monitoring milk for strontium-90 in November 1955. At first analyses were carried out on samples of powdered milk obtained from processing plants. However, since January 1963 liquid whole milk has been analyzed instead. With this change, more representative samples of milk consumed can be obtained, and in addition it is possible to choose milk sampling locations (see figure 8) in the same areas as the air and precipitation stations. At present, the analyses include determinations of iodine-131, strontium-89, cesium-137, and strontium-90 as well as stable potassium and calcium.

The milk samples are obtained through the cooperation of the Marketing Division of the Canadian Department of Agriculture. At each station samples are collected three times a week from selected dairies and are combined into weekly composites and forwarded to the radiochemical laboratory in Ottawa. The contribution of each dairy to the composite sample is directly proportional to its volume of sales. In most cases a complete sample represents over 80 percent of the milk processed and distributed in the area. Several of the weekly samples are randomly selected and analyzed for iodine-131. The results of the spot checks for iodine-131 will not be reported unless there is evidence that the levels are rising. A monthly composite of the samples is analyzed for strontium-90, cesium-137, and stable potassium and calcium.

Analytical Methods

Radiochemical methods are used for the analysis of iodine-131 (*8*). For the analysis of radiostrontium, carrier strontium is added to a one-liter sample of milk, and the milk is then placed in a tray lined with a polyethylene sheet and evaporated under infra-red lamps. The residue is ashed in a muffle furnace at 450° C, dissolved in dilute nitric acid, and strontium separated by fuming nitric acid precipitation. The combined strontium-89 and strontium-90 are determined by counting in a low background beta counter. Strontium-90 is determined separately by extracting and counting its

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[3] Data from *Radiation Protection Programs, Vol. 2, No. 9:* 25-30, Radiation Protection Division, Canadian Department of National Health and Welfare (Sept. 1964).

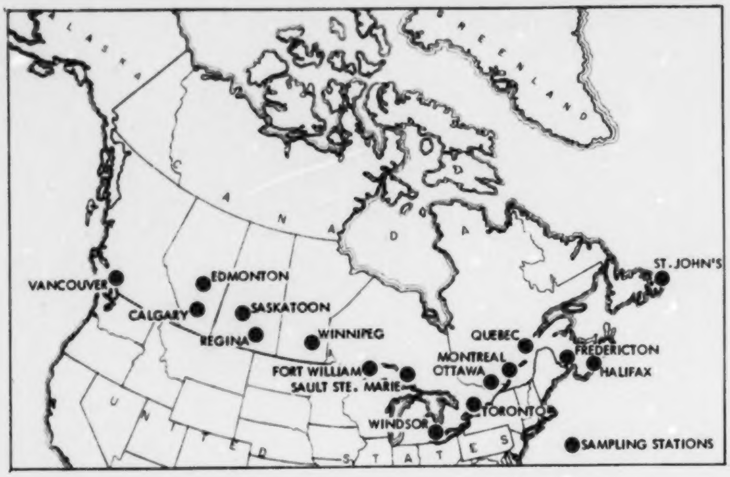

FIGURE 8.—CANADIAN MILK SAMPLING STATIONS

yttrium-90 daughter, while strontium-89 is estimated by difference from the total radiostrontium measurement. Appropriate corrections are made for self-absorption and counter efficiency at all stages. Calcium is determined by flame photometry.

Cesium-137 is determined by gamma spectroscopy using a scintillation crystal and a multi-channel pulse height analyzer. A sample consisting of 4.5 liters of milk is placed in a sample tray constructed in the form of an inverted well to accommodate the 5- x 4-inch sodium iodide crystal detector. The sample is counted for 100 minutes and the gamma spectrum recorded. Estimates are made of the potassium-40 and cesium-137 content of the milk by comparison of the spectrum with the spectra of standard preparations of these two radionuclides. With this method the potassium-40 concentration is determined and the Compton contribution of this radionuclide to the cesium-137 photopeak is subtracted to obtain the cesium-137 concentration. The stable potassium content is estimated from the potassium-40 concentration.

Sources of Error

In the iodine and strontium determinations, tests indicate that the statistical error (95 percent confidence level) in the chemical operations involved is about plus-or-minus 10 percent. This value is independent of the concentration of the radioisotope in the milk because it depends only on the recovery of the carrier. In the determination of cesium-137 this factor is not involved.

The chemical procedures error must be combined with the counting error which depends primarily on the concentration of the nuclide in the sample, the background radiation, and the length of time the sample and background are counted. This counting error has been evaluated mathematically for the particular counting arrangement used.

The overall errors, estimated on the basis indicated above, are given in table 9.

TABLE 9.—TOTAL ERROR FOR VARIOUS RADIONUCLIDE CONCENTRATIONS IN MILK[a]

Nuclide	Error for 10 pc/liter	Error for 50 pc/liter	Error for 100 pc/liter
Strontium-89	±25%	±20%	±15%
Strontium-90	±15%	±10%	±10%
Iodine-131	±50%	±20%	±10%
Cesium-137	±60%	±25%	±10%

[a] All errors are 2σ values, representing 95 percent confidence levels.

Results

Table 10 presents monthly averages of strontium-90, cesium-137 and stable calcium and potassium in Canadian whole milk. Spot checks for iodine-131 and strontium-89 indicate that all samples had <5 pc/liter.

TABLE 10.—RADIONUCLIDES IN CANADIAN WHOLE MILK, AUGUST 1964

[Radionuclide concentration in pc/liter]

Station	Calcium (g/liter)	Potassium (g/liter)	Strontium-90	Cesium-137
Calgary	1.14	1.5	26.3	119
Edmonton	1.12	1.5	26.6	133
Ft. William	1.09	1.5	36.1	200
Fredericton	1.12	1.6	44.2	245
Halifax	1.12	1.7	47.2	272
Montreal	1.00	1.7	22.4	134
Ottawa	1.08	1.6	19.4	118
Quebec	1.06	1.7	39.6	207
Regina	1.08	1.6	29.7	120
St. John's, Nfld	1.14	1.6	74.8	376
Saskatoon	1.12	1.6	29.9	119
Sault Ste. Marie	1.08	1.5	32.7	191
Toronto	1.08	1.6	11.6	94
Vancouver	1.12	1.6	39.1	286
Windsor	1.08	1.6	14.0	67
Winnipeg	1.09	1.6	25.6	122
Average	1.10	1.6	32.5	175

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(2) Public Health Service: Milk Surveillance, Pasteurized Milk Network, March 1964, *Radiological Health Data, 5:* 309–17 (July 1964).

(3) State of California Department of Public Health: California Milk Network, 1960-June 1962, *Radiological Health Data 4:* 90–92 (February 1963).

(4) Heslep, J. M. and A. C. Cornish: California Milk Network and Milkshed Comparisons, April-June 1963, *Radiological Health Data, 4:* 596–9 (December 1963).

(5) Division of Radiological and Occupation Health, Florida State Board of Health: Florida Milk Network, *Radiological Health Data, 5:* 121–22 (March 1964).

(6) Porter, C., D. Cahill, R. Schneider, P. Robbins, W. Perry, and B. Kahn: Determination of Strontium–90 in Milk by an Ion Exchange Method, *Analytical Chemistry, 33:* 1306–8 (September 1961).

(7) Kahn, B., *et. al.: Rapid Methods for Estimating Fission Product Concentrations in Milk, Public Health Service Publication No. 999–R–2,* (March 1963). Single copies available on request from Public Inquiries Branch, PHS, U.S. Department of Health, Education, and Welfare, Washington, D. C. 20201.

(8) DasGupta, A. K. and H. G. Green: *A Method for the Radiochemical Determination of Iodine–131 in Milk, RPD–23,* Radiation Protection Division, Department of National Health and Welfare, Ottawa, Canada (October 1963).

MOVING ANNUAL AVERAGE RADIONUCLIDE CONCENTRATIONS IN PASTEURIZED MILK, SEPTEMBER 1963–AUGUST 1964

Division of Radiological Health, Public Health Service

Radionuclide concentration values reported by the Pasteurized Milk Network (*1*) can be used to estimate the contribution of milk to a population's radiation exposure. This is done by determining both the annual average concentrations of specific radionuclides in milk and the average daily milk consumption of a representative individual in a suitable sample of the population.

The data listed in table 1 are concerned with the first of these requirements, *i.e.*, annual average concentrations of strontium–89, strontium–90, and cesium–137 in one liter of pasteurized milk. Limited data are available for estimating the average daily milk consumption (on a volume basis) for specific age groups in the U.S. population (*2, 3*).

To arrive at a basis of comparison between the daily rates of intake of the radionuclides from the milk component of the diet and the Federal Radiation Council's ranges of transient daily rates of intake (*4*), it is assumed that the average daily milk consumption of an individual in a population group is one liter. The Guides, however, apply to total intake from all sources. The upper limits of Range II correspond to the Radiation Protection Guide (RPG) for iodine–131 and to one-third of the RPG for radioactive strontium. The Guides are, for administrative reasons, expressed as a yearly radiation dose, but are based on lifetime exposure (*5*). The FRC emphasizes that the annual acceptable risk or exposure dose is not a dividing line between safety and danger in actual radiation situations (*6*).

Annual averages of radionuclide concentrations in milk sampled by the PHS Pasteurized Milk Network are presented in table 1. The data in table 1 are calculated as follows: Results from all samples collected in each week (Sunday through Saturday) are averaged, and the averages for all weeks terminating in each of twelve consecutive months are averaged to obtain the annual average.[1] To obtain the annual average daily intake (pc/day) of radionuclides from milk, the annual average concentration values (pc/liter) in table 1 must be multiplied by the annual average daily consumption (liters/day) of milk.

Monthly variations of radionuclide concentrations in milk are influenced by a number of combined causes such as weather conditions and dairying practices. The moving yearly average (table 1), obtained by updating the previous twelve-month average by one month, shows variations averaged over the year and tends to minimize purely seasonal variations. This method, therefore, shows trends over a considerable period of time.

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[1] Beginning with the October 1963 data, iodine–131 values of <10 pc/liter are considered to be zero for averaging purposes; previously, 5 pc/liter was used for calculating the averages.

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(*1*) Public Health Service: Milk Surveillance—Pasteurized Milk Network, *Radiological Health Data*, 5:57–61 (February 1964).

(*2*) Bureau of the Census, and Public Health Service: National Food Consumption Survey, Fresh Whole Milk Consumption in the United States, July 1962, *Radiological Health Data 4:* 15–17 (January 1963).

(*3*) Bureau of the Census and Public Health Service: Consumption of Selected Food Items in U. S. Households, July 1962, *Radiological Health Data, 4:* 124–7.

(*4*) Federal Radiation Council: Radiation Protection Guidance for Federal Agencies, *Federal Register: 9957–8*, Superintendent of Documents, Government Printing Office, Washington, D. C. 20402 (September 26, 1961).

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TABLE 1.—MOVING ANNUAL AVERAGE RADIONUCLIDE CONCENTRATIONS IN MILK[a b]

[Concentrations in pc/liter]

Sampling locations		Strontium-89		Strontium-90		Cesium-137	
		Aug 1963–July 1964	Sept 1963–Aug 1964	Aug 1963–July 1964	Sept 1963–Aug 1964	August 1963–July 1964	Sept 1963–Aug 1964
Ala:	Montgomery	10	5	23	23	89	87
Alaska:	Palmer	16	12	26	25	164	154
Ariz:	Phoenix	3	3	4	4	26	26
Ark:	Little Rock	21	9	46	45	157	141
Calif:	Sacramento	4	3	9	9	55	53
	San Francisco	6	5	10	10	63	60
Colo:	Denver	10	8	20	19	93	93
Conn:	Hartford	10	6	24	23	173	162
Del:	Wilmington	9	5	26	25	140	134
D. C:	Washington	9	6	20	20	94	90
Fla:	Tampa	7	4	15	15	246	245
Ga:	Atlanta	15	8	33	32	149	142
Hawaii:	Honolulu	5	4	11	11	82	82
Idaho:	Idaho Falls	18	14	29	28	183	179
Ill:	Chicago	7	5	21	20	124	121
Ind:	Indianapolis	9	5	23	22	108	102
Iowa:	Des Moines	13	10	27	26	98	96
Kans:	Wichita	9	7	22	21	72	71
Ky:	Louisville	19	19	34	32	106	97
La:	New Orleans	16	9	50	51	157	152
Maine:	Portland	14	8	34	33	233	219
Md:	Baltimore	12	7	23	23	116	107
Mass:	Boston	16	9	37	36	265	247
Mich:	Detroit	8	5	20	20	126	121
	Grand Rapids	9	5	22	22	136	132
Minn:	Minneapolis	19	14	35	34	163	158
Miss:	Jackson	16	9	42	42	116	112
Mo:	Kansas City	15	12	30	29	89	86
	St. Louis	11	9	24	24	90	87
Mont:	Helena	16	10	31	29	205	190
Nebr:	Omaha	14	11	28	27	102	101
Nev:	Las Vegas	8	7	11	11	83	81
N. H:	Manchester	14	8	35	34	276	259
N. J:	Trenton	9	6	21	20	130	123
N. Mex:	Albuquerque	6	4	12	12	56	56
N. Y:	Buffalo	9	6	23	22	159	152
	New York	13	8	31	29	190	176
	Syracuse	11	7	24	22	161	152
N. C:	Charlotte	15	8	35	36	123	119
N. Dak:	Minot	24	16	61	60	162	159
Ohio:	Cincinnati	9	5	25	24	100	96
	Cleveland	8	5	22	22	124	118
Okla:	Oklahoma City	10	6	24	23	78	74
Ore:	Portland	15	12	33	32	178	177
Pa:	Philadelphia	7	4	22	21	132	125
	Pittsburgh	11	6	32	31	108	159
P. R:	San Juan	7	4	13	13	77	74
R. I:	Providence	9	5	27	26	184	175
S. C:	Charleston	7	2	31	31	135	132
S. Dak:	Rapid City	23	15	45	45	166	159
Tenn:	Chattanooga	20	10	42	41	136	128
	Memphis	13	7	33	33	81	77
Tex:	Austin	4	3	9	9	45	44
	Dallas	8	4	20	20	74	70
Utah:	Salt Lake City	15	11	27	27	187	187
Vt:	Burlington	13	7	30	28	206	195
Va:	Norfolk	9	5	23	23	102	98
Wash:	Seattle	15	12	29	29	167	165
	Spokane	16	12	30	30	152	150
W. Va:	Charleston	16	8	29	28	95	89
Wis:	Milwaukee	7	4	19	19	141	136
Wyo:	Laramie	22	11	22	22	117	116
Network average		12	8	26.4	25.9	132	127

[a] Averages based on 52 weeks except for Syracuse where averages were based on 48 weeks.
[b] Iodine-131 and barium-140 averages were <10.

(5) Federal Radiation Council: *Background Material for the Development of Radiation Protection Standards, Report No. 2*, Superintendent of Documents U. S. Government Printing Office, Washington, D. C. 20402 (September 1961). Price 20 cents.

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STRONTIUM-90 IN TRI-CITY DIETS, FEBRUARY-APRIL 1964[1]

Health and Safety Laboratory, AEC

Since March 1960, the Health and Safety Laboratory, through its quarterly diet study, has made estimates of the strontium–90 content of the average diet of individuals living in New York City, San Francisco, and Chicago.

Selected foods representing 19 food categories are purchased at each of these three cities about every 3 months and are analyzed for strontium–90. Using data from the U.S. Department of Agriculture (*1*) the annual consumption by an average individual can be grouped into the same 19 food categories. The annual dietary intake of strontium–90 can be estimated by summing the contributions from each category. Some food types are assumed to be representative of larger food categories, such as liquid milk for dairy products in general.

The consumption data (*1*) are based on a weight-as-purchased basis. Before the food samples for the Tri-City Diet Study are ashed for radiochemical analysis, they are prepared to a certain degree as if for actual consumption. For example, fruits are peeled, eggs are shelled, and poultry is boned. Therefore, concentrations of radiocactivity in foods are reported in the Tri-City Diet Study are based on the trimmed weight. No correction is made for the waste.

After two samplings at each city it was found that the calcium content of most food categories did not vary among cities, nor did it vary significantly with time. Calcium analyses of dietary components were performed for the third time recently, and further confirmed this result (*2*). Calcium analyses were therefore discontinued and average calcium content of foods was computed and used to estimate the average annual intake of this mineral. Details of the sampling system and a discussion of the results obtained have been summarized (*3*).

Results obtained from the February-April 1964 sampling are presented in table 1. The variation with time of the daily intake of strontium–90 in the three cities is plotted in figure 1.

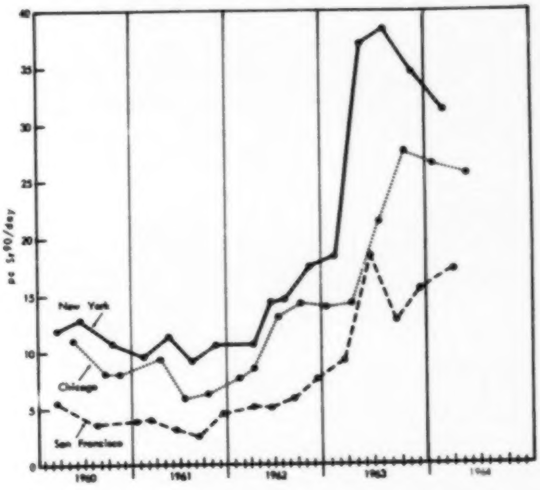

FIGURE 1.—DAILY INTAKE OF STRONTIUM–90 IN TRI-CITY DIETS

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[1] Summarized from *Fallout Program Quarterly Summary Report, HASL–149:* 51–3, Office of Technical Services, Department of Commerce, Washington, D. C. 20230 (October 1, 1964) price $2.75.

TABLE 1.—AVERAGE PER PERSON DIETARY CONSUMPTION AND STRONTIUM-90 INTAKE

Food category	Average U.S. consumption		New York City February 1964		Chicago April 1964		San Francisco March 1964	
	diet (kg/yr)	Calcium (g/yr)	pc/kg [a]	pc/yr	pc/kg [a]	pc/yr	pc/kg [a]	pc/yr
Bakery products	37	37.0	26.3±1.1	973	25.9±1.3	958	25.0±1.3	925
Whole grain products	11	10.0	101 ±2.4	1,111	81.5±2.4	896	47.4±2.1	521
Eggs	16	9.1	8.3±0.3	133	9.8±0.2	157	5.5±0.2	88
Fresh vegetables	43	15.0	13.9±0.6	598	16.7±0.5	718	3.2±0.3	138
Root vegetables	17	6.1	9.6±0.5	163	9.8±0.5	167	8.7±0.5	148
Milk	221	234.3	25.9±0.8	5,724	18.0±0.5	3,974	15.2±0.6	3,359
Poultry	17	9.2	3.3±0.2	56	1.7±0.1	29	2.8±0.1	48
Fresh fish	8	10.8	0.9±0.2	7	4.0±0.2	32	0.7±0.1	6
Flour	43	8.6	21.3±0.4	916	23.6±0.5	1,015	10.9±0.5	469
Macaroni	3	0.7	18.4±0.5	55	24.4±0.7	73	10.5±0.4	32
Rice	3	1.1	4.8±0.2	14	5.5±0.3	16	4.8±0.2	14
Meat	73	10.9	1.9±0.1	139	1.5±0.1	110	1.4±0.8	102
Shellfish	1	0.8	3.9±0.2	4	1.1±0.1	1	3.0±0.2	3
Dried beans	3	2.9	36.0±1.8	108	29.4±1.8	88	10.2±1.0	30
Fresh fruit	68	13.6	9.8±0.4	666	5.9±0.4	401	2.6±0.3	177
Potatoes	45	5.8	8.5±0.7	382	6.9±0.7	310	3.1±0.3	140
Canned fruit	26	1.3	3.6±0.2	93	1.9±0.2	49	1.9±0.2	49
Fruit juices	19	1.7	4.1±0.3	78	4.1±0.2	78	3.4±0.2	65
Canned vegetables	20	4.2	8.6±0.6	172	10.1±0.6	202	2.7±0.3	54
Annual intake	674	383	16.8	11,392	13.8	9,274	9.4	6,368 16.6
pc Sr^{90}/g Ca in total diet	----------	----------	----------	29.7	----------	24.2		

[a] Error terms are one standard deviation (due to counting).

Discussion

The previously noted geographic pattern of distribution of strontium-90 in the diet is seen to persist in the last sampling: levels have been highest in New York City and lowest in San Francisco. Partly due to its high annual consumption, milk continues to be the predominant source of strontium-90 in the diet.

In Chicago the strontium-90 intake was about the same as that found three months earlier. There was a slight increase in the strontium-90 intake estimated for San Francisco and a slight decrease for New York.

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(1) U. S. Department of Agriculture: *Food Consumption of Households in the United States, Report No. 1, 1955*, Household Food Consumption Survey Superintendent of Documents, Government Printing Office, Washington, D. C. 20402 (December 1956), price $1.00.

(2) U. S. Atomic Energy Commission: *Fallout Program Quarterly Summary Report, HASL–144*: 281–7, Office of Technical Services, Department of Commerce, Washington, D. C. 20230 (April 1, 1964), price $4.00. Summarized in *Radiological Health Data*, p. 285–8, June 1964.

(3) Rivera, J. and J. H. Harley: *HASL Contributions to the Study of Fallout in Food Chains, HASL–147*, Office of Technical Services, Department of Commerce, Washington, D. C. 20230 (July 1, 1964), price $1.50.

Recent coverage in *Radiological Health Data:*

Period	Issue
Thirteenth sampling (May-July 1963)	*March 1964*
Fourteenth sampling (August-October 1963)	*June 1964*
Fifteenth sampling (November 1962-January 1964)	*September 1964*

Section III—Water

GROSS RADIOACTIVITY AND STRONTIUM-90 IN SURFACE WATERS OF THE UNITED STATES, JUNE 1964

Division of Water Supply and Pollution Control, Public Health Service

Levels of radioactivity in surface waters of the United States have been monitored by the Public Health Service Water Pollution Surveillance System since its initiation in 1957. Beginning with the establishment of 50 sampling points, this system has expanded to 131 stations as of October 1, 1964. These are operated jointly with other Federal, State, and local agencies, and industry. Samples are taken from surface waters of all major U.S. river basins for physical, chemical, biological and radiological analyses. These data can be used for evaluating sources of radioactivity which may affect specific domestic, commercial, and recreational uses of surface water. Further, the system provides background information necessary for recognizing pollution and water quality trends and for determining levels of radioactivity to which the population may be exposed. Data assembled through the system and exact locations of sampling points are published in annual compilations (*1–7*).

Sampling Procedures

The participating agencies collect one-liter "grab" samples each week and ship them "as is" to the Surveillance System Laboratory in Cincinnati for analysis. Gross alpha and gross beta radioactivity determinations on the suspended and dissolved solids are performed as frequently as deemed necessary.

Presently, gross alpha and beta determinations are made on monthly composites of the weekly samples received from most stations. Weekly alpha and beta determinations are scheduled for stations located downstream from known potential sources of radioactive waste. Weekly analyses are also conducted at all newly established stations for the first year of operation.

Normally, samples are counted within two weeks following collection or within one week after compositing. The decay of activity is followed on each sample for which the first analysis shows unusually high activity. Also, if a recount indicates that the original analysis was questionable, values based on recounting are recorded. All results are reported for the time of counting and are not extrapolated to the time of collection.

Analytical Methods

The analytical method used for determining gross alpha and beta radioactivity is described in the eleventh edition of "Standard Methods for the Examination of Water and Wastewater" (*8*). Suspended and dissolved solids are separated by passing the sample through a membrane filter (type HA) with a pore size of 0.45 micron. Planchets are then prepared for counting the dissolved solids (in the filtrate) and the suspended solids (on the charred mem-

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brane filter) in an internal proportional counter. Reference sources of U_3O_8, which give a known count rate if the instrument is in proper calibration, are used for daily checking of the counters.

Results

Table 1 presents June 1964 results of alpha and beta analysis of U.S. surface waters. The stations on a river are arranged in the table according to their relative location on the river, the first stations listed being closest to the headwaters. These data are preliminary. Replicate analyses of some samples as well as some analyses incomplete at the time of this report will be included in the system's "Annual Compilation of Data" (*7*). The figures for gross alpha and gross beta radioactivity represent either determinations on composite samples or means of weekly determinations where composites were not made. The monthly means are reported to the nearest pc/liter. When all samples have zero pc/liter, the mean is reported as zero; when the calculated mean is between zero and 0.5 the mean is reported as <1 pc/liter.

A geographical perspective of the radioactivity in surface water is obtained from the numbers printed near the stations as shown in figure 1 which gives the June 1964 average total beta activity in suspended-plus-dissolved solids in raw water collected at each station. Results for the years 1957-1962 have been summarized by Weaver *et al* (*9*).

Strontium–90 Determinations and Results

Beginning in 1959, strontium–90 analyses of the total solids of surface waters were made quarterly on three-month composites of aliquots from weekly samples. Beginning in November 1962, the frequency of analysis was reduced to two quarterly samples per year at each sampling point except those stations immediately below nuclear installations, where quarterly analyses were continued. The method used for determining strontium–90 is a modification of a procedure described by Harley (*10*). The yttrium–90 together with an yttrium carrier is precipitated as yttrium oxalate and the latter is washed and counted in a low-background anticoincidence, end-window proportional counter.

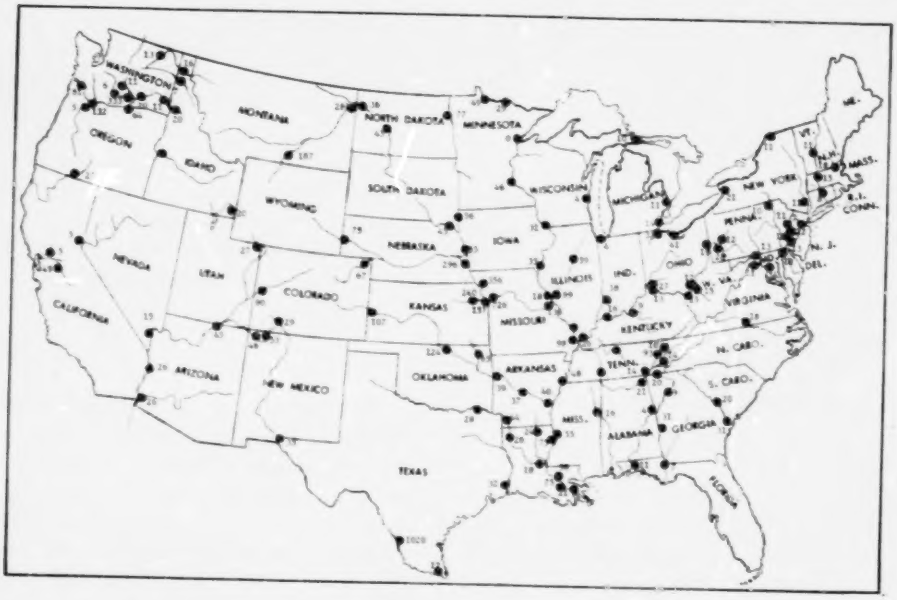
WASHINGTON
OREGON
IDAHO
MONTANA
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
WYOMING
NEVADA
UTAH
CALIFORNIA
COLORADO
NEBRASKA
IOWA
WISCONSIN
MICHIGAN
ILLINOIS
IND.
OHIO
KANSAS
MISSOURI
KENTUCKY
ARIZONA
NEW MEXICO
OKLAHOMA
ARKANSAS
TENN.
TEXAS
MISS.
ALABAMA
GEORGIA
FLORIDA
S. CARO.
N. CARO.
VIRGINIA
W. VA.
PENNA.
NEW YORK
N. J.
DEL.
CONN.
R. I.
MASS.
VT.
N. H.
ME.

FIGURE 1.—SAMPLING LOCATIONS AND ASSOCIATED TOTAL BETA ACTIVITY (pc/liter) IN SURFACE WATERS, JUNE 1964

TABLE 1.—RADIOACTIVITY IN RAW SURFACE WATERS, JUNE 1964

[Average concentrations in pc/liter]

Station	Beta activity			Alpha activity		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Allegheny River:						
Pittsbugh, Pa	0	12	12	0	0	0
Animas River:						
Cedar Hill, N. Mex	39	14	53	0	1	1
Apalachicola River:						
Chattahoochee, Fla	0	7	7	0	0	0
Arkansas River:						
Coolidge, Kansas	49	58	107	8	16	24
Ponca City, Okla	87	37	124	7	0	7
Fort Smith, Ark	39	0	39	14	3	17
Little Rock, Ark	13	24	37	2	2	4
Pendleton Ferry, Ark	13	27	40	2	2	4
Atchafalaya River:						
Morgan City, La	41	34	75	9	0	9
Bear River:						
Preston, Idaho	2	18	20	1	2	3
Big Horn River:						
Hardin, Mont	155	32	187	26	2	28
Big Sioux River:						
Sioux Falls, S. Dak	16	40	56	1	4	5
Chattahoochee River:						
Atlanta, Ga	6	3	9	1	0	1
Lanett, Ala	0	4	4	0	0	0
Columbus, Ga	20	11	31	3	0	3
Chena River:						
Fairbanks, Alaska	0	10	10	0	0	0
Clearwater River:						
Lewiston, Idaho	12	8	20	2	0	2
Clinch River:						
Clinton, Tenn	1	9	10	0	<1	<1
Kingston, Tenn	14	79	93	0	<1	<1
Colorado River:						
Loma, Colo	60	20	80	13	2	15
Page, Ariz	4	41	45	0	9	9
Boulder City, Nev	1	14	15	0	2	2
Parker Dam, Calif-Ariz	1	25	26	0	20	20
Yuma, Ariz	4	22	26	1	12	13
Columbia River:						
Northport, Wash	1	12	13	0	0	0
Wenatchee, Wash	2	9	11	0	0	0
Pasco, Wash	119	214	333	0	<1	<1
McNary Dam, Ore	20	44	64	<1	<1	<1
Bonneville, Ore	54	78	132	0	1	1
Clatskanie, Ore	27	54	81	<1	0	<1
Connecticut River:						
Wilder, Vt	4	7	11	1	0	1
Northfield, Mass	8	7	15	1	0	1
Enfield Dam, Conn	0	8	8	1	0	1
Cuyahoga River:						
Cleveland, Ohio	7	34	41	0	1	1
Delaware River:						
Martins Creek, Pa	2	9	11	0	0	0
Trenton, N. J	9	13	22	0	1	1
Philadelphia, Pa	0	12	12	0	0	0
Escambia River:						
Century, Fla	4	7	11	0	0	0
Great Lakes:						
Duluth, Minn	0	0	0	0	0	0
Sault Ste. Marie, Mich	0	10	10	0	0	0
Milwaukee, Wis	0	4	4	0	0	0
Gary, Ind	0	4	4	0	0	0
Port Huron, Mich	1	10	11	0	0	0
Detroit, Mich	3	11	14	1	1	2
Buffalo, N. Y	5	16	21	0	0	0
Green River:						
Dutch John, Utah	0	27	27	0	0	0
Hudson River:						
Poughkeepsie, N. Y	2	9	11	0	0	0
Illinois River:						
Peoria, Ill	10	29	39	2	4	6
Grafton, Ill	3	15	18	1	3	4
Kanawha River: Winfield Dam, W. Va	2	13	15	0	1	1
Kansas River:						
De Soto, Kans	202	38	240	17	2	19
Klamath River:						
Keno, Ore	2	25	27	0	1	1
Little Miami River:						
Cincinnati, Ohio	11	16	27	1	1	2
Maumee River:						
Toledo, Ohio	6	31	37	0	2	2
Merrimack River:						
Lowell, Mass	5	13	18	0	0	0
Mississippi River:						
St. Paul, Minn	6	40	46	0	0	0
Dubuque, Iowa	0	31	31	0	0	0
Burlington, Iowa	10	25	35	0	0	0
E. St. Louis, Ill	89	0	89	28	1	29
Cape Girardeau, Mo	66	32	98	5	3	8
W. Memphis, Ark	25	23	48	8	1	9
Vicksburg, Miss	32	23	55	8	2	10
Delta, La	47	28	75	10	1	11
New Roads, La	32	26	58	6	1	7
New Orleans, La	9	12	21	2	1	3
Missouri River:						
Williston, N. Dak	9	27	36	0	1	1
Bismarck, N. Dak	12	31	43	1	5	6
Yankton, S. Dak	2	43	45	0	4	4
Omaha, Nebr	26	29	55	8	5	13
St. Joseph, Mo	173	183	356	26	3	29
Kansas City, Kans	132	25	157	30	4	34
Missouri City, Mo	669	57	726	271	4	275
St. Louis, Mo	112	24	136	25	2	27
Monongahela River:						
Pittsburgh, Pa	3	25	28	0	0	0
North Platte River:						
Henry, Nebr	26	49	75	2	19	21
Ohio River:						
Toronto, Ohio	0	19	19	0	0	0
Addison, Ohio	0	12	12	0	0	0
Huntington, W. Va	3	12	15	0	0	0
Cincinnati, Ohio	5	8	13	1	0	1
Louisville, Ky	0	9	9	0	0	0
Evansville, Ind	0	16	16	0	1	1
Cairo, Ill	7	19	26	1	0	1
Ouachita River:						
Bastrop, La	6	18	24	0	1	1
Pend Oreille River:						
Albeni Falls Dam, Idaho	8	8	16	1	1	2
Platte River:						
Plattsmouth, Nebr	261	35	296	30	2	32
Potomac River:						
Williamsport, Md	1	12	13	0	0	0
Great Falls, Md	2	12	14	0	0	0
Washington, D.C	4	10	14	<1	<1	<1
Rainy River:						
Baudette, Minn	10	39	49	0	1	1
International Falls, Minn	4	25	29	0	0	0
Raritan River:						
Perth Amboy, N. J. (5 ft. Below Surface)	0	7	7	0	3	3
Perth Amboy, N. J. (5 ft. Above Bottom)	0	12	12	0	4	4
Red River, North:						
Grand Forks, N. Dak	19	58	77	0	5	5
Red River, South:						
Denison, Tex	3	25	28	0	4	4
Index, Ark	1	43	44	0	3	3
Bossier City, La	3	25	28	0	2	2
Alexandria, La	13	5	18	0	1	1
Rio Grande River:						
Alamosa, Colo	9	20	29	1	1	2
El Paso, Tex	15	20	35	3	3	6
Laredo, Tex	985	35	1,020	156	2	158
Brownsville, Tex	2	15	17	0	1	1
Roanoke River:						
John H. Kerr Resr/Dam, Va	5	13	18	0	0	0
Sabine River:						
Ruliff, Tex	13	19	32	1	0	1
Sacramento River:						
Courtland Calif	0	5	5	0	0	0
St. Lawrence River:						
Massena, N. Y	4	7	11	0	0	0
San Joaquin River:						
Vernalis, Calif	10	39	49	2	19	21
San Juan River:						
Shiprock, N. Mex	25	21	46	4	6	10
Savannah River:						
North Augusta, S. C.	5	15	20	0	0	0
Port Wentworth, Ga.	15	16	31	1	0	1
Schuylkill River:						
Philadelphia, Pa	1	12	13	0	1	1
Shenandoah River:						
Berryville, Va	0	11	11	0	0	0
Ship Creek:						
Anchorage, Alaska	6	5	11	0	0	0
Snake River:						
Ice Harbor Dam, Wash	4	7	11	0	0	0
Wawawai, Wash	10	10	20	1	0	1
South Platte River:						
Julesburg, Colo	1	66	67	0	36	36
Spokane River:						
Post Falls Dam, Idaho	4	3	7	0	0	0
Susquehanna River:						
Sayre, Pa	6	4	10	0	1	1
Conowingo, Md	2	8	10	0	0	0
Tennessee River:						
Lenoir City, Tenn	5	9	14	0	0	0
Chattanooga, Tenn	2	18	20	<1	0	<1
Bridgeport, Ala	5	16	21	0	0	0
Pickwick Landing, Tenn	3	11	14	0	0	0
Tombigbee River:						
Columbus, Miss	5	11	16	0	0	0
Truckee River:						
Farad, Calif	0	5	5	1	0	1
Verdigris River:						
Nowata, Okla	41	24	65	3	1	4
Wabash River:						
New Harmony, Ind	21	17	38	3	0	3
Willamette River:						
Portland, Ore	3	2	5	0	0	0
Yakima River:						
Richland, Wash	1	5	6	0	0	0
Yellowstone River:						
Sidney, Mont	248	33	281	72	3	75
Maximum	985	214	1,020	271	36	275
Minimum	0	0	0	0	0	0

Note: These data are preliminary; reanalysis of some samples may be made and additional analysis not completed at the time of the report may become available. For final data, one should consult the system's annual report.

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TABLE 2.—QUARTERLY AVERAGE STRONTIUM-90 CONCENTRATIONS IN SURFACE WATERS, JULY 1963–JUNE 1964

[Concentrations in pc/liter]

Station	July–Sept. 1963	Oct.–Dec. 1963	Jan.–Mar. 1964	Apr.–June 1964
Allegheny River:				
Pittsburgh, Pa	[a]—	2.8	—	2.3
Animas River:				
Cedar Hill, N. Mex	1.8	—	1.7	—
Apalachicola River:				
Chattahoochee, Fla	2.9	—	1.5	—
Arkansas River:				
Coolidge, Kans	6.6	—	0.9	—
Ponca City, Okla	6.5	4.4	—	6.0
Fort Smith, Ark	6.7	—	3.5	—
Little Rock, Ark	4.8	4.4	—	4.2
Pendleton Ferry, Ark	—	4.3	—	4.4
Bear River:				
Preston, Idaho	3.7	—	1.1	—
Big Horn River:				
Hardin, Mont	—	2.3	—	6.4
Big Sioux River:				
Sioux Falls, S. Dak	9.5	5.0	2.8	—
Chattahoochee River:				
Atlanta, Ga	—	1.7	—	2.4
Columbus, Ga	—	1.7	—	2.0
Lanett, Ala	2.0	—	1.7	—
Chena Slough:				
Fairbanks, Alaska	—	0.2	—	0.8
Clearwater River:				
Lewiston, Idaho	1.2	—	0.8	—
Clinch River:				
Clinton, Tenn	1.4	—	2.0	—
Kingston, Tenn	9.4	6.5	7.5	4.9
Colorado River:				
Loma, Colo	—	1.4	—	2.5
Page, Ariz	4.2	—	5.9	—
Boulder City, Nev	—	1.5	—	1.6
Parker Dam, Calif-Ariz	1.0	—	1.9	—
Yuma, Ariz	—	1.1	—	1.0
Columbia River:				
Northport, Wash	3.4	—	1.5	—
Wenatchee, Wash	—	2.8	—	1.2
Pasco, Wash	2.7	3.4	3.1	1.7
McNary Dam, Ore	2.6	2.5	2.2	1.1
Bonneville, Ore	1.2	—	2.0	—
Clatskanie, Ore	2.5	1.6	—	1.0
Connecticut River:				
Wilder, Vt	2.6	—	1.3	—
Northfield, Mass	3.1	1.8	—	1.5
Enfield Dam, Conn	2.5	—	1.7	—
Cumberland River:				
Clarksville, Tenn	2.0	—	—	—
Cuyahoga River:				
Cleveland, Ohio	5.3	—	4.3	—
Delaware River:				
Martins Creek, Pa	—	1.6	—	1.5
Trenton, N. J	3.1	—	1.8	—
Philadelphia, Pa	—	2.1	—	2.0
Escambia River:				
Century, Fla	—	1.2	—	1.8
Great Lakes:				
Duluth, Minn	—	0.7	—	0.7
Sault Ste. Marie, Mich	1.5	—	0.8	—
Milwaukee, Wis	—	0.8	—	1.2
Gary, Ind	1.6	—	1.2	—
Port Huron, Mich	—	1.2	—	1.5
Detroit, Mich	2.4	—	1.4	—
Buffalo, N. Y	—	2.5	—	2.7
Green River:				
Dutch John, Utah	2.7	—	4.6	—
Hudson River:				
Poughkeepsie, N. Y	—	5.0	—	2.1
Illinois River:				
Peoria, Ill	—	2.3	—	3.8
Grafton, Ill	4.4	—	3.8	—
Kanawha River:				
Winfield Dam, W. Va	2.9	—	1.1	—
Kansas River:				
De Soto, Kans	7.4	5.2	—	5.9
Klamath River:				
Keno, Ore	—	1.8	—	1.7
Little Miami River:				
Cincinnati, Ohio	5.3	1.4	3.3	—
Maumee River:				
Toledo, Ohio	—	2.7	—	4.2
Merrimack River:				
Lowell, Mass	1.6	—	1.8	—
Mississippi River:				
St. Paul, Minn	7.2	4.3	3.2	—
Dubuque, Iowa	—	3.7	—	5.2
Burlington, Iowa	7.3	4.3	2.8	—
E. St. Louis, Ill	—	3.8	—	4.9
Cape Girardeau, Mo	5.3	—	2.9	—
W. Memphis, Ark	—	3.6	—	4.3
Vicksburg, Miss	4.2	—	2.7	—
Delta, La	—	3.4	3.6	—
New Roads, La	—	—	—	3.6
New Orleans, La	4.5	—	2.8	—
Missouri River:				
Williston, N. Dak	—	2.8	—	3.1
Bismarck, N. Dak	3.5	—	3.9	—
Yankton, S. Dak	—	3.3	—	4.3
Omaha, Nebr	4.5	—	3.3	—
St. Joseph, Mo	—	3.4	—	6.4
Kansas City, Kans	5.0	—	2.9	—
Missouri City, Mo	—	4.1	—	9.4
St. Louis, Mo	6.2	—	3.1	—
Monongahela River:				
Pittsburgh, Pa	3.3	3.3	—	2.1
North Platte River:				
Henry, Nebr	—	0.7	—	3.3
Ohio River:				
Toronto, Ohio	4.9	2.8	—	2.3
Addison, Ohio	4.0	—	2.2	—
Huntington, W. Va	—	3.0	—	2.2
Cincinnati, Ohio	3.7	—	1.6	—
Louisville, Ky	3.6	4.0	—	2.6
Evansville, Ind	4.2	—	2.5	—
Cairo, Ill	—	2.8	—	3.4
Ouachita River:				
Bastrop, La	4.5	—	3.0	—
Pend Oreille River:				
Albeni Falls Dam, Idaho	—	1.3	—	1.2
Platte River:				
Plattsmouth, Nebr	5.2	—	2.1	—
Potomac River:				
Williamsport, Md	—	1.7	—	1.3
Great Falls, Md	2.5	—	1.4	—
Washington, D. C	3.4	—	1.2	—
Rainy River:				
Baudette, Minn	4.7	4.1	—	4.0
International Falls, Minn	4.3	3.8	—	5.0
Red River, North:				
Grand Forks, N. Dak	11.3	7.1	4.9	9.4
Red River, South:				
Denison, Tex	5.6	—	5.8	—
Index, Ark	4.9	4.3	—	5.4
Bossier City, La	5.0	—	4.4	—
Alexandria, La	—	4.1	—	4.4
Rio Grande River:				
Alamosa, Colo	—	0.8	—	1.9
El Paso, Tex	1.9	—	0.6	—
Laredo, Tex	—	2.4	—	5.6
Brownsville, Tex	2.3	—	2.6	—
Roanoke River:				
John H. Kerr Resr/Dam, Va	—	2.6	—	1.5
Sabine River:				
Ruliff, Tex	3.2	—	2.5	—
Sacramento River:				
Courtland, Calif	1.4	1.0	1.0	—
St. Lawrence River:				
Massena, N. Y	2.3	—	1.6	—
San Joaquin River:				
Vernalis, Calif	—	1.5	—	1.0
San Juan River:				
Shiprock, N. Mex	—	2.1	—	2.9
Savannah River:				
North Augusta, So. Car	2.1	—	1.7	—
Port Wentworth, Ga	3.2	2.4	1.7	2.3
Schuylkill River:				
Philadelphia Pa	3.7	—	1.4	—
Shenandoah River:				
Berryville, Va	—	1.0	—	1.1
Ship Creek:				
Anchorage, Alaska	0.9	—	0.4	—
Snake River:				
Ice Harbor Dam, Wash	1.3	—	1.0	—
Wawawai, Wash	—	0.7	—	1.0
Payette, Idaho	—	0.8	—	0.9
South Platte River:				
Julesburg, Colo	—	1.8	—	1.6
Spokane River:				
Post Falls, Idaho	1.2	—	1.3	—
Susquehanna River:				
Sayre, Pa	2.3	—	1.3	—
Conowingo, Md	—	3.0	—	1.3
Tennessee River:				
Lenoir City, Tenn	—	2.1	—	1.6
Chattanooga, Tenn	3.3	2.2	2.0	2.3
Bridgeport, Ala	—	2.2	—	1.5
Pickwick Landing, Tenn	2.5	—	2.1	—
Tombigbee River:				
Columbus, Miss	3.6	—	3.1	—
Truckee River:				
Farad, Calif	—	1.0	—	1.2
Verdigris River:				
Nowata, Okla	—	6.0	—	6.6
Wabash River:				
New Harmony, Ind	—	2.5	—	4.2
Willamette River:				
Portland, Ore	—	0.5	—	0.3
Yakima River:				
Richland, Wash	1.0	—	0.3	—
Yellowstone River:				
Sindey, Mont	5.0	—	1.9	—
Maximum	11.3	7.1	7.5	9.4
Minimum	0.9	0.2	0.8	0.3

[a] No sample reported.

Table 2 presents the results of quarterly analyses of strontium-90 concentrations in U.S. surface waters for April-June 1964 as well as results for the previous three quarters for comparative purposes. The stations are arranged in the table according to their relative locations on the river, the first station being closest to the headwaters. Floyd and Weaver summarized the strontium-90 results obtained from 1959 through 1963 in the August 1964 issue of *RHD* (*11*).

Sixty-nine quarterly composite samples were analyzed for strontium-90 activity in April-June 1964. The arithmetic mean for these 69 results was 3.0 pc/liter and the median was 2.3 pc/liter. The mean for 64 results of the previous quarter (January, February, March 1964) was 2.5 and the median was 2.0 pc/liter. This increase can be attributed largely to seasonal "runoff".

Two stations had strontium-90 levels equal to or greater than 7.5 pc/liter, which was the highest reported level during the previous quarter. These were Grand Forks (Red River North) and Missouri City (Missouri River), both with 9.4 pc/liter. While there are no standards for strontium-90 activity of total solids in surface water, the Public Health Service Drinking Water Standards set the limit for strontium-90 concentrations in drinking water at 10 pc/liter (*12*). This limit for public water supplies is greater than the highest level observed during April-June 1964.

Discussion

The monthly dissolved beta activity averages exceeded 100 pc/liter at two stations. These values were 214 pc/liter on the Columbia River and 183 pc/liter on the Missouri River. The gross beta activity (quarterly median of monthly means) for this period for the original radioactivity-baseline stations was 43 pc/liter, compared to 27 pc/liter for the previous quarter.

The dissolved alpha activity, which is associated with the dissolving of natural surface minerals by water, ranged from zero to 36 pc/liter. Of all stations, six stations on five rivers had monthly average dissolved alpha activity greater than 10 pc/liter.

The radioactivity associated with dissolved solids provides a rough indication of the levels which could occur in treated water, since nearly all suspended matter is removed by the treatment process (*13*). The Public Health Service Drinking Water Standards state that in the absence of strontium-90 and alpha emitters,[1] a water supply is acceptable when the gross beta concentration does not exceed 1000 pc/liter (*12*).

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[1] Absence is taken here to mean a negligibly small fraction of the specific limits of 3 pc/liter and 10 pc/liter for unidentified alpha emitters and strontium-90, respectively.

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(*2*) *Ibid.*, 1959 Edition. Price $1.75.

(*3*) *Ibid.*, 1960 Edition.[2]

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(*5*) *Ibid.*, 1962 Edition.[2]

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(*10*) Harley, J. H.: Radiochemical Determinations of Strontium-90, *Health and Safety Laboratory Manual of Standard Procedures*, August 1962 Revision, Radiochemistry and Environmental Studies Division, HASL, U. S. Atomic Energy Commission, New York Operations Office (1962).

(*11*) Floyd, E. P. and L. Weaver: Trends of Strontium-90 Levels in Surface Waters of the United States, 1959-1963, *Radiological Health Data 5:* 390–94 (August 1964).

(*12*) Public Health Service: *Drinking Water Standards, Revised 1962, Public Health Service Publication No. 956*, Superintendent of Documents, Government Printing Office, Washington, D. C. 20402 (March 1963), price 30 cents.

(*13*) Straub, C. P.: Significance of Radioactivity Data, *Journal of the American Water Works Association, 53:* 704 (June 1961).

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[2] Single free copies of this publication may be obtained from: Public Inquiries Branch, Public Health Service, U. S. Department of Health, Education, and Welfare, Washington, D. C. 20201.

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RADIOACTIVITY IN NEW YORK SURFACE WATER JULY 1963—JUNE 1964

Division of Environmental Health Services
State of New York Department of Health

The New York Department of Health began a program in January 1955 to determine the amount of radioactivity in water used for public consumption. This radioactivity in water may arise from the natural mineral content of water (background), from atmospheric fallout, and from nuclear industry operations. Water samples are obtained monthly from twenty-six cities for gross beta analysis. Samples are obtained more frequently from four cities for strontium–90 analyses.

Samples are sent to the Division of Laboratories and Research for analysis. Table 1 shows the gross beta concentrations and table 2 shows the radiostrontium concentrations in water from January 1963–June 1964. Albany and Cohoes water receives standard chlorination, coagulation and gravity rapid sand filtration and New York City receives chlorination. It is of note that the Cohoes gross beta results are for the raw water source while the Cohoes strontium–89 and strontium–90 results are for the finished water.

TABLE 1.—GROSS BETA ACTIVITY IN NEW YORK RAW SURFACE WATER, NOVEMBER 1963–JUNE 1964

[Concentration in pc/liter]

Location	1963		1964					
	November	December	January	February	March	April	May	June
Akron (Murder Creek) [a]	13	21	16	13	15	11	11	13
Bedford (Byram Lake) [b]	18	8	9	3	23	15	15	10
Cape Vincent (St. Lawrence R.) [b]	—	—	—	—	Began in April	6	—	—
Clarkstown (Congers Lake) [b]	33	—	22	15	25	56	26	28
Clarkstown (Lake De Forest) [b]	<3	—	18	20	13	21	12	10
Cohoes (Mohawk River) [e]	13	26	9	9	11	—	—	7.0
Glenmont (Hudson River) [d]	13	17	9	9	11	12	8	7.5
Haverstraw (Letchworth V. Res.) [b]	10	—	8	5	7	7	5	5
Highland Falls (Bog Meadow Brook) [b]	4	5	6	<3	11	5	12	5
Niagara Falls (W. Branch Niagara River) [b]	5	—	7	—	8	11	—	7
Niagara Falls (E. Branch Niagara River) [b]	7	—	6	—	11	16	—	9
Ossining (Hudson R.) (Sing Sing) [a]	53	30	58	56	20	13	27	36
Ossining (Indian Bank Res.) [b]	28	—	13	16	15	20	13	7
Oswego (Lake Ontario) [e]	7	6	6	10	7	7	6	6
Pawling (Pond at United Nuclear) [b]	25	18	7	16	20	<	12	8
Peekskill (Hudson River) [c]	21	23	24	12	12	10	9	22
Peekskill (Camp Fields WS) [c]	21	11	9	13	10	19	8	10
Ramapo (Hillburn WS) [b]	17	—	9	5	3	12	6	3
Rome (Fish Creek) [a]	15	16	10	8	13	14	8	8
Schenectady (Mohawk River) [c]	10	13	8	5	11	11	8	7
Stony Point (Iowa Island W.S.) [b]	<3	—	5	<3	8	6	1	5
Tuxedo (Indian Kill Outfall) [c]	18	15	7	<3	7	13	7	9
Waterford (Hudson River) [a]	9	10	13	13	23	14	7	5
Watertown (Black River) [b]	15	17	23	12	14	16	9	8
Watervliet (French Mills Res.) [b]	8	9	18	11	12	6	7	5
Yorktown (Croton Res.) [c]	14	9	<3	3	14	21	19	10

[a] Bi-weekly composite of daily grab samples.
[b] Monthly grab sample.
[c] Continuous bleed-off analyzed weekly.
[d] Weekly composite of daily grab samples.
[e] Weekly grab sample.

TABLE 2.—STRONTIUM-89 AND STRONTIUM-90 LEVELS IN NEW YORK WATER

[Average concentrations in pc/liter]

Location	1963						1964				
	July	August	September	October	November	December	January	February	March	April	May
Albany [a]											
Strontium-89	<3	5	5	7	5	<3	<3	<3	<3	<3	<3
Strontium-90	3	<3	<3	<3	<3	<3	3	<3	4	3	3
Cohoes [b]											
Strontium-89	6	10	12	15	4	<3	<3	<3	<3	<3	<3
Strontium-90	7	7	6	9	9	6	5	<3	<3	<3	4.5
Geneva [c]											
Strontium-89	<3	<3	<3	3	<3	<3	<3	<3	<3	<3	<3
Strontium-90	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
New York City											
Strontium-89	4	8	7	9	<3	<3	<3	<3	<3	<3	<3
Strontium-90	4	<3	<3	<3	<3	<3	<3	<3	3	<3	<3

[a] Weekly composite of daily grab samples.
[b] Continuous bleed-off analyzed weekly.
[c] Bi-weekly composite of daily grab samples.

For gross beta analysis, a measured quantity of water is evaporated and the residue is analyzed in an end-window gas flow proportional counter.

For strontium–89, strontium–90 and yttrium–90 analysis, a measured quantity of water is passed through an ion exchange resin column and the strontium is retained on the resin. The strontium is then eluted from the resin, concentrated and beta counted as strontium sulfate using a low background end-window gas flow proportional counter. Successive beta counting of the sample at two-day intervals enables the determination of strontium–90, strontium–89 and yttrium–90 to be made.

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Section IV—Other Data

ENVIRONMENTAL LEVELS OF RADIOACTIVITY AT ATOMIC ENERGY COMMISSION INSTALLATIONS

The U.S. Atomic Energy Commission receives from its contractors semi-annual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant perimeter surveys are required.

Summaries of the environmental radioactivity data for 22 AEC installations have appeared periodically in *RHD* since November 1960. Summaries follow for Brookhaven National Laboratory and Rocky Flats Plant.

Releases of radioactive materials from these installations for the periods covered in the reports below are regulated in accordance with AEC standards as set forth in the Federal Register Title 10—Part 20 (*1*). The appropriate concentration standards are given in table 1.

1. Brookhaven National Laboratory
July 1963-June 1964

Associated Universities, Inc.
Upton, New York

The Brookhaven National Laboratory (BNL) operations may affect the environmental levels of radiation in three ways: (1) by discharge of coolant air from the graphite research reactor, (2) by radiation from an ecology forest gamma source, and (3) by the discharge of low level radioactive liquid wastes into a small stream that forms one of the headwaters of the Peconic River (figure 1).

TABLE 1.—SELECTED ENVIRONMENTAL MPC VALUES PERTAINING TO AEC INSTALLATION REPORTS IN THIS SUBSECTION

Line No.	Radionuclide or mixture of unknown nuclides	Environmental MPC's	
		Water (pc/liter)	Air (pc/m^3)
1	If Sr^{90}, I^{129}, Pb^{210}, Po^{210}, At^{211}, Ra^{223}, Ra^{224}, Ra^{226}, Ac^{227}, Ra^{228}, Th^{230}, Pa^{231}, Th^{232}, and Th-nat are not present [b]	3,000	—
2	If Sr^{90}, Pb^{210}, Ra^{226}, Ra^{228} are not present [b]	600	—
3	If Ra^{226}, Ra^{228} are not present [b]	100	—
4	Mixture of unidentified nuclides	10	0.04
5	If α emitters and Ac^{227} are not present [b]	—	1.0
6	If α emitters and Pb^{210}, Ac^{227}, Ra^{228}, Pu^{241} are not present [b]	—	10
7	If α emitters and Sr^{90}, I^{129}, Pb^{210}, Ac^{227}, Ra^{228}, Pa^{230}, Pu^{241}, Bk^{249} are not present [b]	—	100
8	Argon-41 (immersion)	—	40,000
9	Plutonium-239	5,000	0.06
10	Uranium-natural	20,000	2

[a] The concentration standards given here were taken from The Atomic Energy Commission's regulation 10 CFR Part 20, Federal Register, (*1*).

[b] "Not present" implies that the concentration of the nuclide is small compared with its appropriate MPC. According to Federal Register, Title 10, Part 20, (*1*), a group of nuclides may be considered not present if the ratio of each nuclide to its appropriate MPC is equal to or less than 1/10 and if the sum of these ratios for the group in question is equal to or less than ¼.

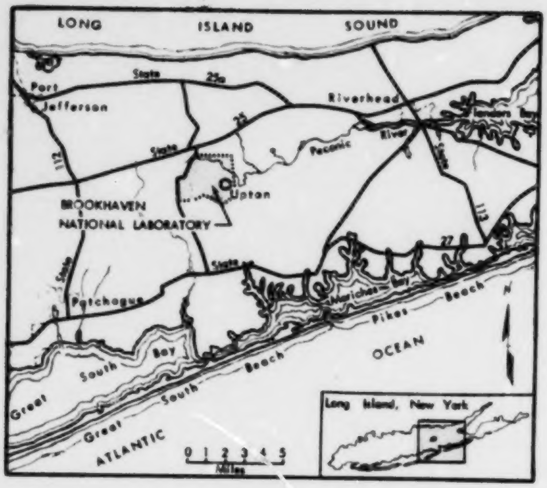
LONG ISLAND SOUND
Port Jefferson
State 25a
Riverhead
25
State
Peconic River
112
Upton
BROOKHAVEN NATIONAL LABORATORY
State
Patchogue
27
113
Moriches Bay
Pikes Beach
Great South Bay
South Beach
Great South Beach
OCEAN
ATLANTIC
0 1 2 3 4 5
Miles
N
Long Island, New York

FIGURE 1.—BROOKHAVEN NATIONAL LABORATORY AND SURROUNDING AREA

TABLE 2.—EXTERNAL GAMMA LEVELS AT BNL SITE BOUNDARY

(Average exposure rates in mr/wk)

Period	North gate [1]	Southwest perimeter	Southeast perimeter	Northeast perimeter
Gamma exposure from laboratory operations				
1963				
July	0.47	0.25	0.42	3.56
August	0.17	0.01	0.48	3.13
September	0.21	0.70	0.27	2.45
October	0.41	0.57	0.53	2.50
November	0.31	0.39	0.45	2.17
December	0.19	0.25	0.39	1.63
1964				
January	0.15	0.13	0.43	1.45
February	0.11	0.08	0.92	1.42
March	0.20	0.51	0.65	2.55
April	0.54	0.39	0.44	2.36
May	0.25	0.98	0.23	2.83
June	0.27	0.43	0.52	3.36
Second half 1963	0.29	0.35	0.42	2.61
First half 1964	0.25	0.43	0.52	2.33
Undisturbed background				
Second half 1963	5.94	5.41	5.92	5.89
First half 1964	2.78	2.90	3.13	3.28

[1] North gate station is located 680 meters inside boundary. The others are on the boundary.

Area Monitoring

The radioactivity in the discharge coolant air is almost entirely that of argon–41, a beta-gamma emitter. Because exposure to argon–41 is due to external gamma, the monitoring is performed by measuring the exposure-rate in milliroentgens per week (mr/wk) rather than the concentration in air.

Late in 1961 a 10,000 curie cesium–137 gamma source was installed in the ecology forest about 800 meters equidistant from the north and east boundaries (*2*).

Table 2 presents the average external gamma exposure rates measured at the four stations shown in figure 2. The higher levels at the Northeast perimeter station are primarily due to the ecology forest source. The environmental maximum permissible dose recommended by the FRC is 0.5 rem/yr (10 mrem/wk) above natural background, averaged over a one-year period.

Water Monitoring

The BNL liquid waste effluent is monitored for gross beta concentrations at the site boundary. Table 3 presents the average concentration together with the total activity released as determined by using known effluent flow rates.

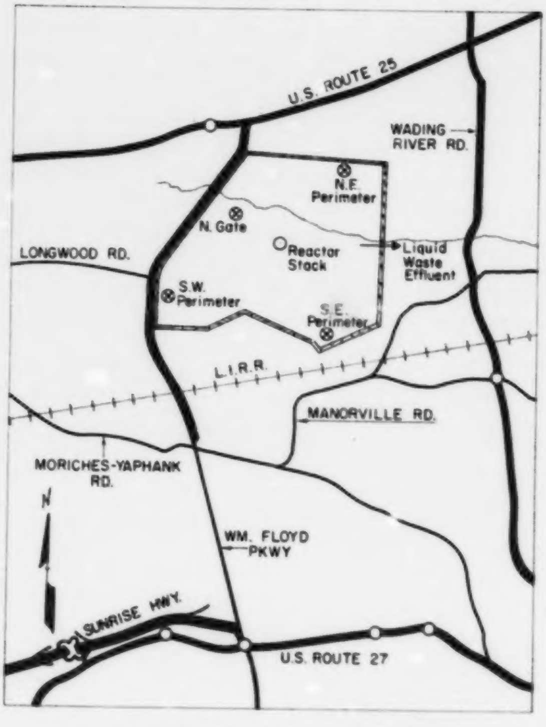
U.S. ROUTE 25
WADING RIVER RD.
N.E. Perimeter
N. Gate
LONGWOOD RD.
Reactor Stack
Liquid Waste Effluent
S.W. Perimeter
S.E. Perimeter
L.I.R.R.
MANORVILLE RD.
MORICHES-YAPHANK RD.
N
WM. FLOYD PKWY
SUNRISE HWY.
U.S. ROUTE 27

FIGURE 2.—BROOKHAVEN NATIONAL LABORATORY MONITORING STATION LOCATIONS

TABLE 3.—GROSS BETA ACTIVITY IN BNL LIQUID WASTE EFFLUENT

Period	Average beta concentration (pc/liter)	Total beta activity discharged (mc)
1963		
July	103	9.3
August	71	7.0
September	115	10.9
October	86	6.9
November	95	7.1
December	80	5.7
1964		
January	53	5.1
February	79	6.0
March	83	6.3
April	43	4.8
May	77	9.1
June	128	11.1
Second Half 1963	92	46.9
First Half 1964	75	42.4

Previous coverage in *Radiological Health Data*:

Period	Issue
1959 and first quarter 1960	*December 1960*
Second quarter 1960	*February 1961*
Third and fourth quarters 1960	*June 1961*
First and second quarters 1961	*January 1962*
Third and fourth quarters 1961	*June 1962*
First and second quarters 1962	*January 1963*
July 1962 to June 1963	*February 1964*

2. Rocky Flats Plant
July 1963-June 1964

Dow Chemical Company, Denver, Colorado

The Rocky Flats Plant (RFP) is engaged in routine production operations involving plutonium under contract to the Atomic Energy Commission. Its location relative to population centers is shown in figure 3. To assure properly controlled release of radioactive materials to the environment, periodic samples of water, air, and vegetation are analyzed for gross alpha activity. The most abundant radioactive material involved in the process is plutonium.

The plant is located on gravel washed out of the highly mineralized Front Range of the Rocky Mountains, where heterogeneous low-level deposits of uranium, thorium, and radium exist in the soil. These materials are measurable in most samples of air, water, and vegetation.

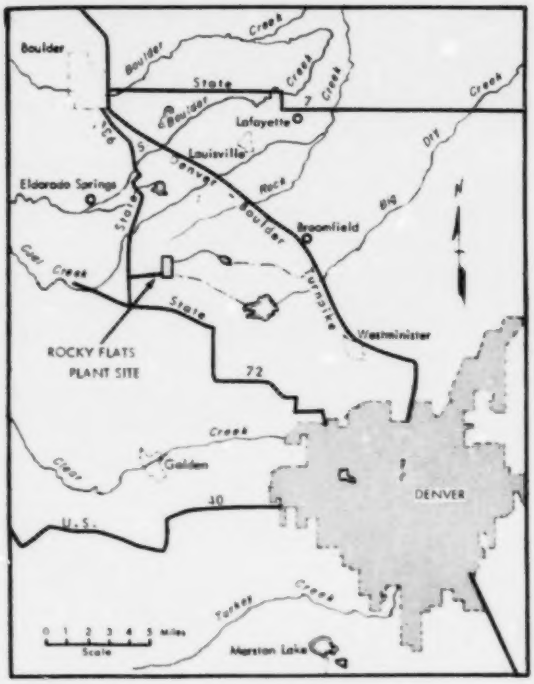
Boulder
Boulder Creek
State
Creek
7 Creek
Creek
Boulder
Lafayette
Louisville
Dry
Eldorado Springs
Denver - Boulder Turnpike
Rock
Broomfield
Big
N
Coal Creek
State
State
ROCKY FLATS PLANT SITE
Westminister
72
Creek
Clear
Golden
DENVER
40
U.S.
Turkey Creek
0 1 2 3 4 5 Miles
Scale
Marston Lake

FIGURE 3.—LOCATION OF THE ROCKY FLATS PLANT ENVIRONMENT, DENVER, COLORADO

Air

Continuous 24-hour air samples were collected at Coal Creek Canyon, Marshall, Boulder, Lafayette, Broomfield, Wagner School, Golden, Denver, and Westminster. The monthly average long-lived gross alpha activities are shown in table 4. The alpha activity is believed to consist entirely of naturally occurring materials.

TABLE 4.—LONG-LIVED ALPHA ACTIVITY IN PARTICULATES IN AIR, RFP

Month	Average alpha concentration (pc/m³)
1963	
July	<0.002
August	<0.001
September	<0.005
October	<0.003
November	<0.005
December	<0.007
1964	
January	<0.007
February	<0.005
March	<0.009
April	<0.007
May	0.013
June	<0.003

Water Monitoring

Semi-monthly water samples were collected from four reservoirs at distances ranging from 3 to 8 miles from RFP. The average alpha concentrations in the four reservoirs during the second half of 1963 and first half of 1964 are shown in table 5.

Non-routine raw surface water samples were collected from a number of outlying streams and lakes during fall and spring vegetation collections. The 35 samples collected during the second half of 1963 had an average gross alpha activity of 2.1 pc/liter. The semiannual sampling was postponed for the first half of 1964.

TABLE 5.—ALPHA ACTIVITY IN RESERVOIRS IN THE VICINITY OF ROCKY FLATS PLANT

[Average concentrations in pc/liter]

Reservoir	Second half 1963	First half 1964
Great Western	2.2	3.2
Standley	2.5	2.7
Baseline	1.7	1.4
Ralston	1.4	3.9

Vegetation Samples

A total of 281 vegetation samples were analyzed during the 12-month period covered by this report. The average gross alpha activities of these samples are shown in table 6.

TABLE 6.—GROSS ALPHA ACTIVITY IN VEGETATION

Samples collected	Analysis made	Distance from plant	Number of samples	Average concentration (pc/kg dry)
1963	1963	<3 miles	30	111
	1963	3-18 miles	12	99
1962-1963	1964	<3 miles	100	154
		3-18 miles	24	134
1963	1964	<3 miles	72	200
		3-18 miles	43	210

Previous coverage in *Radiological Health Data:*

Period	Issue
Second half 1960 and First half of 1961	*November 1961*
Second half 1961	*May 1962*
First half 1962	*January 1963*
July 1962 and June 1963	*February 1964*

REFERENCES

(*1*) U. S. Atomic Energy Commission: *Rules and Regulations, Standards for Protection Against Radiation, Title 10 CFR 20,* Government Printing Office, Washington, D. C.

(*2*) Hull, A. P.: 1962 Environmental Radiation Levels at Brookhaven National Laboratory, BNL 807 (T-310) (Health and Safety—TID—4500, 21st Ed) May 1963, Office of Technical Services, Department of Commerce, Washington D. C., 20430.

RADIONUCLIDES IN ALASKAN CARIBOU AND REINDEER, 1962-1964

Division of Radiological Health, Public Health Service

A new phase in assessing the radionuclide intake of Alaskan residents began in 1963, when caribou and reindeer sampling and analysis were undertaken by the Alaskan Departments of Health and Welfare and of Fish and Game and the Public Health Service under a cooperative agreement between these agencies. The basis for this joint activity stemmed from a more limited sampling effort conducted by these groups in 1962.

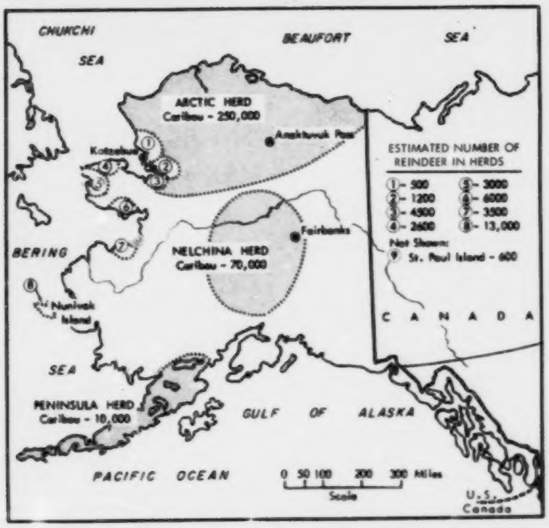
CHUKCHI SEA
BEAUFORT SEA
ARCTIC HERD
Caribou - 250,000
Anaktuvuk Pass
Kotzebue
ESTIMATED NUMBER OF REINDEER IN HERDS
①- 500
②- 1200
③- 4500
④- 2600
⑤- 3000
⑥- 6000
⑦- 3500
⑧- 13,000
Not Shown:
⑨ St. Paul Island - 600
Fairbanks
NELCHINA HERD
Caribou - 70,000
BERING SEA
Nunivak Island
CANADA
PENINSULA HERD
Caribou - 10,000
GULF OF ALASKA
PACIFIC OCEAN
0 50 100 200 300 Miles
Scale
U.S.
Canada

FIGURE 1.—NUMBERS OF RUMINANTS IN HERDS SAMPLED, 1964

Through the second quarter of 1964, the sampling was confined to the three principal caribou (*Rangifer caribou*) herds and one privately owned reindeer (*Rangifer tarandus*) herd. This program was expanded when, beginning in September 1964, the sampling of additional privately-owned reindeer herds was begun through the assistance of the Fish and Wildlife Service and Bureau of Indian Affairs, Department of Interior.

Figure 1 shows the locations and approximate number of animals in the caribou and reindeer herds sampled. In general, the reindeer herds are located on or near the Seward peninsula and on two islands off the western coast of Alaska.

Samples of muscle rumen contents and bone from 5 animals (two- or three-years old) in each herd sampled are collected in approximately April, July, September and December of each year. The muscle samples, weighing about two pounds each, are frozen for shipment. The bone samples consist of the hock from each animal. The rumen content samples, weighing about two pounds wet, are dried for shipment. All samples are shipped in dry ice to the Public Health Service Southwestern Radiological Health Laboratory in Las Vegas, Nevada, for analysis.

The analytical procedure includes gamma scintillation spectroscopy for potassium–40, zirconium-niobium–95, ruthenium–106, and cesium–137. Strontium–89 and strontium–90 are determined by chemical separation followed by beta counting. Analysis for stable calcium is done by a flame photometric method.

Zirconium-niobium–95, ruthenium–106 and cesium–137 results are presented in tables 1-3 for caribou and reindeer muscle, rumen contents and bone, respectively. Data for cesium–137 in caribou muscle and rumen contents are shown in figures 2 and 3.

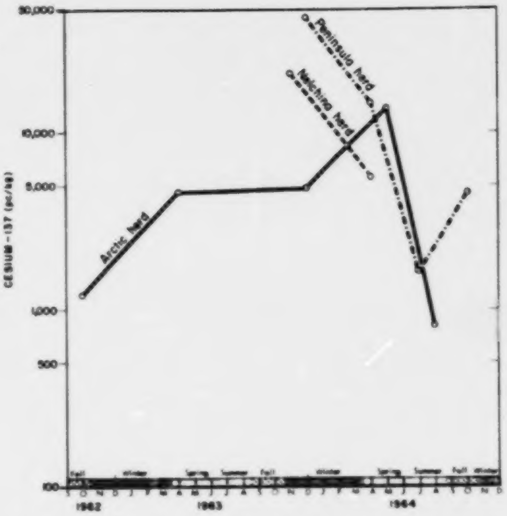

FIGURE 2.—CESIUM-137 IN CARIBOU MUSCLE

TABLE 1.—RADIONUCLIDES IN ALASKAN CARIBOU AND REINDEER MUSCLE

Specimens & sampling dates	(pc/kg wet weight)				
	Sr^{89}	Sr^{90}	$Zr\text{-}Nb^{95}$	Ru^{106}	Cs^{137}
Caribou					
Arctic herd					
10/2/62	<5	25	<10	<10	740
10/2/62	<5	74	<10	<10	<10
10/2/62	<5	79	<10	250	1,200
10/2/62	<5	73	<10	710	1,500
10/2/62	<5	85	<10	970	1,400
4/23/63	<5	15	<10	<10	4,400
4/23/63	<5	9	<10	<10	2,200
4/23/63	40	32	<10	<10	4,700
4/24/63	<5	12	<10	<10	6,200
4/24/63	<5	14	<10	<10	5,500
12/21/63			<10	<10	5,160
12/21/63	• <5	• 17	<10	<10	5,680
12/21/63			<10	80	3,750
4/27/64			<10	<10	21,000
5/3/64			<10	<10	16,000
5/19/64			<10	<10	9,900
5/19/64			<10	<10	17,000
5/19/64			<10	1,300	5,000
8/20/64			<10	<10	740
8/28/64			<10	<10	660
8/28/64			<10	<10	400
8/28/64			<10	<10	1,000
8/29/64			<10	<10	710
Nelchina herd					
11/24/63			<10	2,120	25,500
11/24/63			<10	870	16,900
11/25/63	• 5	• 33	<10	<10	18,200
11/25/63			<10	<10	22,100
11/25/63			<10	1,290	26,400
4/24/64			<10	13,000	3,500
4/24/64			<10	13,000	3,000
4/25/64			<10	12,000	2,600
4/25/64			<10	<10	10,000
4/26/64			<10	<10	8,700
Peninsula herd					
12/12/63			<10	<10	39,400
12/12/63			<10	240	41,500
12/13/63	• 10	• 84	200	190	33,600
12/19/63			<10	<10	57,700
12/19/63			<10	350	51,700
4/9/64			<10	<10	18,000
4/12/64			<10	<10	16,000
4/15/64			<10	<10	12,000
4/15/64			<10	<10	16,000
4/15/64			<10	<10	12,000
7/11/64			<10	<10	1,400
7/11/64			<10	<10	1,800
7/11/64			<10	<10	1,500
7/11/64		<10	<10	<10	2,000
9/26/64			<10	<10	1,200
9/26/64			<10	160	2,380
9/26/64			<10	200	2,090
10/1/64			<10	2,350	9,250
10/1/64			<10	1,190	8,010
Reindeer					
Area 1					
12/27/63			<10	<10	7,540
12/27/63			<10	<10	7,180
12/27/63	• <5	• 31	<10	<10	6,730
12/27/63			<10	<10	7,300
9/7/64			<10	<10	4,900
9/7/64			<10	<10	3,100
9/7/64			<10	920	3,000
9/7/64			<10	<10	3,400
9/7/64			<10	610	2,300
Area 3					
9/26/64			<10	4,540	25,800
9/26/64			<10	1,970	15,400
Area 4					
9/25/64			<10	4,020	770
9/25/64			<10	1,950	10,100
9/25/64			<10	950	7,670
Area 8					
9/18/64			<10	1,410	6,730
9/18/64			<10	<10	8,300
9/18/64			<10	<10	5,930
9/18/64			<10	<10	9,200
9/18/64			<10	<10	5,000
Area 9					
9/24/64			<10	450	5,900
9/24/64			<10	730	3,920
9/24/64			<10	1,200	7,530
9/24/64			<10	990	2,080

• Indicates composite of samples for the period analyzed.

At this stage, comparison of rumen content and muscle concentrations does not reveal any consistent relationship. The need for additional information, including more specific information concerning the dietary habits of caribou is required before meaningful comparisons can be made.

TABLE 2.—RADIONUCLIDES IN ALASKAN CARIBOU AND REINDEER RUMEN CONTENTS

Specimens & sampling dates	(pc/kg)				
	Sr^{89}	Sr^{90}	$Zr\text{-}Nb^{95}$	Ru^{106}	Cs^{137}
Caribou					
Arctic herd					
12/21/63			5,400	3,930	3,980
12/21/63	• 500	• 4,440	5,740	3,910	4,700
12/21/63			5,810	4,390	4,540
4/27/64			<10	13,000	4,100
5/3/64			<10	14,000	4,000
5/19/64			<10	14,000	4,100
5/19/64			<10	13,000	6,000
5/19/64			<10	15,000	4,000
8/20/64			<10	4,300	1,600
8/28/64			<10	5,800	970
8/28/64			<10	2,800	1,200
8/28/64			<10	4,400	2,200
8/29/64			<10	4,100	1,400
Nelchina herd					
11/24/63			12,390	10,370	5,680
11/24/63			9,350	6,460	7,430
11/25/63	• 550	• 5,700	1,910	1,590	1,100
11/25/63			7,970	6,540	4,480
11/25/63			9,410	7,010	5,710
4/24/64			<10	<10	7,500
4/24/64			<10	<10	10,000
4/25/64			<10	9,100	10,000
4/25/64			<10	12,000	2,500
4/26/64			<10	<10	12,000
Peninsula herd					
12/12/63			14,560	6,940	12,300
12/12/63			9,950	4,790	7,280
12/13/63			9,860	5,450	7,360
12/19/63			3,050	6,250	4,020
12/19/63			9,940	4,840	8,660
4/9/64			<10	4,600	2,600
4/12/64			<10	4,900	1,700
4/15/64			<10	3,300	1,600
4/15/64			<10	2,700	1,900
4/15/64			<10	3,200	1,400
7/11/64			<10	<10	620
7/11/64			<10	<10	740
7/11/64			<10	<10	680
7/11/64			<10	<10	670
7/11/64			<10	<10	720
9/26/64			<10	1,600	1,[illegible]
9/26/64			<10	4,350	2,[illegible]
9/26/64			<10	3,500	[illegible],290
10/1/64			<10	13,100	[illegible],550
10/1/64			<10	12,500	[illegible],300
Reindeer					
Area 1					
12/27/63			4,870	2,930	5,150
12/27/63	• 5	• 5000	4,380	2,060	3,760
12/27/63			5,840	3,620	5,360
12/27/63			5,140	2,870	4,320
Area 4					
9/25/64			<10	<10	5,770
Area 8					
9/18/64			<10	<10	3,290
9/18/64			<10	<10	4,510
9/18/64			<10	<10	3,970
Area 9					
9/24/64			<10	<10	660
9/24/64			<10	<10	1,070
9/24/64			<10	<10	1,900

• Indicates composite of samples for the period analyzed.

TABLE 3.—RADIONUCLIDES IN ALASKAN CARIBOU AND REINDEER BONE

Specimens & sampling dates	Sr^{89} (pc/g ash)	Sr^{90} (pc/g ash)	Zr-Nb^{95} (pc/kg) [a]	Ru^{106} (pc/kg) [a]	Cs^{137} (pc/kg) [a]
Caribou					
Arctic herd					
12/21/63	[b] 60	[b] 225	<10	450	190
12/21/63			<10	640	210
12/21/63			<10	910	120
4/27/64			[c] NA	NA	NA
5/3/64			NA	NA	NA
5/19/64	[b] <5	[b] 143	NA	NA	NA
5/19/64			NA	NA	NA
5/19/64			NA	NA	NA
Nelchina herd					
11/24/63			<10	4,550	520
11/24/63			<10	3,210	620
11/25/63	[b] <5	[b] 117	<10	1,910	620
11/25/63			<10	1,510	900
11/25/63			<10	3,860	1,940
4/24/64			NA	NA	NA
4/24/64			NA	NA	NA
4/25/64	[b] <5	[b] 143	NA	NA	NA
4/25/64			NA	NA	NA
4/26/64			NA	NA	NA
Peninsula herd					
12/12/63			460	350	3,240
12/12/63			<10	430	4,780
12/13/63	[b] <5	[b] 118	<10	490	3,740
12/19/63			<10	<10	3,660
12/19/63			<10	380	4,210
4/9/64			NA	NA	NA
4/12/64			NA	NA	NA
4/15/64	[b] <5	[b] 116	NA	NA	NA
4/15/64			NA	NA	NA
4/15/64			NA	NA	NA
9/26/64			<10	820	420
9/26/64			<10	<10	460
10/1/64			<10	400	1,000
10/1/64			<10	550	2,180
Reindeer					
Area 1					
12/27/63			<10	<10	730
12/27/63	[b] 25	[b] 64	<10	<10	850
12/27/63			<10	<10	800
12/27/63			<10	<10	920
9/7/64			<10	<10	2,700
9/7/64			<10	<10	1,300
9/7/64			<10	260	1,500
9/7/64			<10	710	3,400
9/7/64			<10	<10	2,300
Area 3					
9/26/64					1,890
9/26/64			<10	<10	5,460
Area 4					
9/25/64			<10	<10	1,080
9/25/64			<10	590	2,880
9/25/64			<10	840	2,180
Area 8					
9/18/63			<10	<10	1,520
9/18/64			<10	<10	1,380
9/18/64			<10	<10	1,060
9/18/64			<10	<10	1,790
9/18/64			<10	<10	1,340
Area 9					
9/24/64			<10	400	520
9/24/64			<10	390	350
9/24/64			<10	530	610
9/24/64			<10	<10	330

[a] Wet basis.
[b] Indicates composite of samples for the period analyzed.
[c] Indicates no analysis was done.

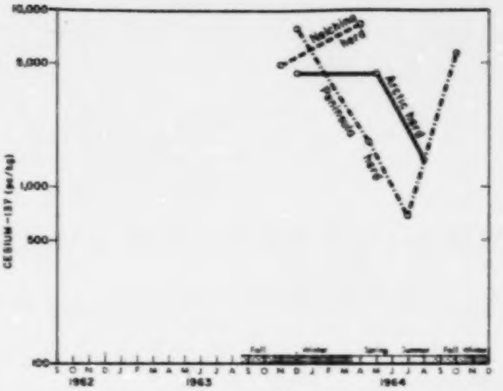

FIGURE 3.—CESIUM-137 IN CARIBOU RUMEN CONTENTS

Although the data are too limited to permit detailed analysis, some observations may be made from the cesium-137 in muscle data for the Arctic Herd. Although a general increasing trend is noted from 1962 through 1963, seasonal variations are difficult to ascertain. Of special interest is the apparent rapid decrease in flesh concentration during the summer of 1964. If the individual data for the Arctic Herd are plotted, they imply an effective half-life for cesium-137 in caribou flesh of approximately 25 days (assuming no intake of cesium-137 during the period). Whether this represents actual turnover in caribou or simply the absence of a close relationship between samples cannot be answered from these data.

STRONTIUM-90 IN HUMAN BONE, 1962-1963

George W. Gaffney, Robert M. Hallisey, Marshall S. Miller, and Abraham S. Goldin[1]

The need to establish Public Health Service programs to provide estimates of accumulations of selected radionuclides in people was emphasized in statements of objectives and feasibility studies initiated in 1961 and 1962 (*1-3*). These estimates would be based on direct measurements in human organs and tissues and would initially include measurement of strontium-90 in bone and iodine-131 in thyroids.

In late 1961 the Public Health Service's Division of Radiological Health, jointly with pathologists and medical examiners throughout the U.S., initiated collection of human bone specimens at autopsies or incidental to surgical procedures. The background of this program, review of previous work, description of analytical methods employed, and initial results from determinations made through October 1963 are given in a previous report (*4*). This report analyzes the results obtained in the program through June 1964, and also gives detailed data for determinations completed from November 1963 through June 1964.

Results

Each determination included in this report represents a separate individual. Table 1 incorporates, for deaths occurring in 1962 and 1963, all results of analyses performed in the Strontium-90 in Human Bone Program through June 1964. This analysis supplants that previously reported (*4*) and includes data for a total of 322 individuals who died in 1962 and 1963 at ages less than 25 years. The present analysis does not include data previously reported for 8 individuals who died in 1961. The program was not designed to include individuals 25 years or older. Analyses from older age groups support the expectation that relatively low strontium-90 to calcium ratios would be found in these cases.

Table 1 contains the highest, lowest, and mean strontium-90 observed in the Programs in bone specimens for each of 5 age ranges and 6 major geographic regions in the United States, as well as for the entire United States. For each category considered, the number of individuals from whom specimens were obtained and analyzed is also given. The 6 major geographic regions (figure 1) have been arbitrarily designated for use in the program (*4*).

Table 2 supplements detailed data which were previously reported (*4*). Details are given for each determination in the program from November 1963 through June 1964.

Figure 2 shows the frequency distribution for strontium-90 in the bone samples from 1962 and 1963 deaths. The distribution is skewed in all of the age ranges considered in this report and the distribution of strontium-90 was observed to be similarly skewed. The logarithmic probability plot presented in figure 3 clearly indicates that the distribution is log-normal, consistent with earlier observations by Kulp and Schulert on whole skeleton samples obtained in New York (*5*).

Figure 4 is a plot of mean strontium-90 versus age for each age range and also a plot of the standard errors of the mean for strontium-90 found for each age group. In view of figures 2 and 3 as noted above, means and standard errors of the mean are certainly not entirely

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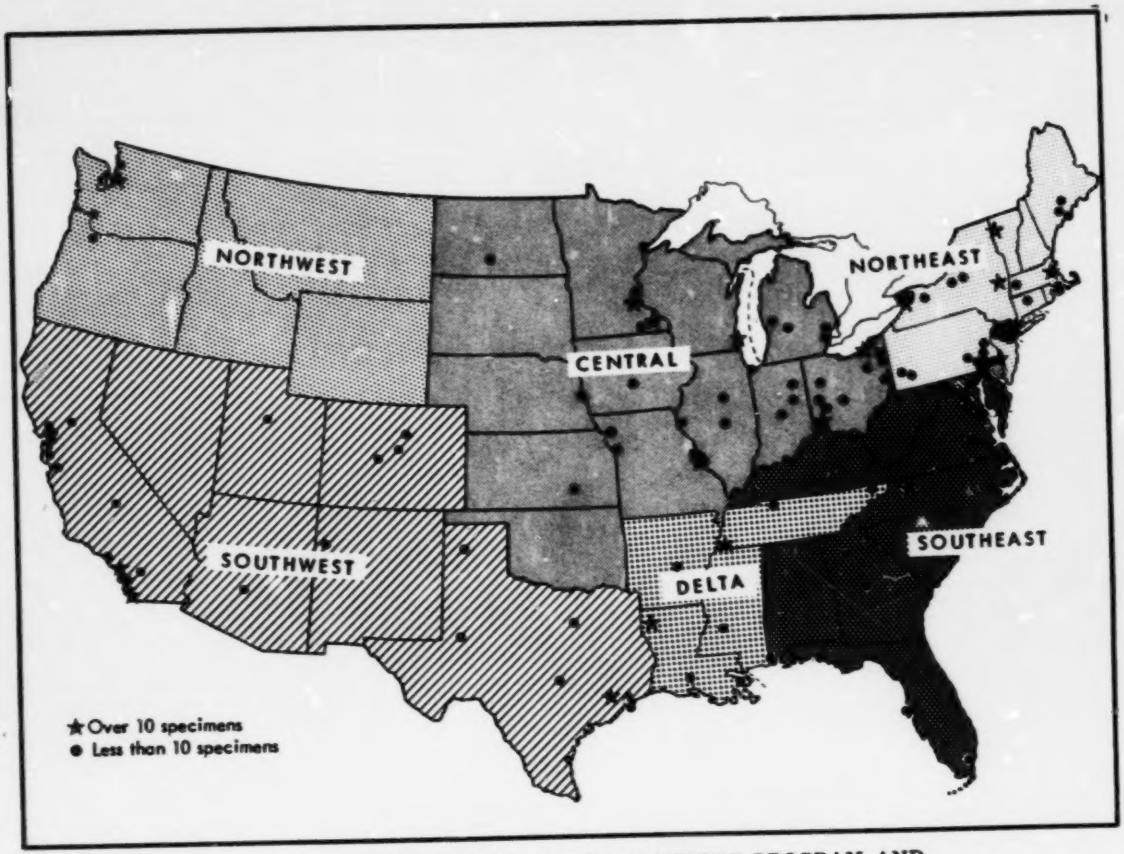

FIGURE 1.—REGIONS FOR PHS BONE SAMPLING PROGRAM AND LOCATION OF COLLECTION CENTERS

satisfactory statistics for these data, which clearly are not normally distributed. Nevertheless, means and standard errors of the mean are given in this report (table 1 and figure 4) because:

1) These have been frequently used by others in reports of strontium-90 in bone; they are in some cases the only basis for comparison with results of previous work by others;
2) Even for a skewed distribution, the mean value could be meaningful for epidemiologic dose and effect interrelationships;
3) The standard error of the mean
    (a) communicates some idea, in an abbreviated summary, of the uncertainty in the central value and,
    (b) combined with information on the number of individuals in the sample, gives some idea of the spread in the distribution of the individual values.

Figure 5 is a plot of median strontium-90 versus age for deaths occurring in 1962 and 1963. In each age group there appeared to be higher median values in samples from 1963 deaths as compared with those which occurred in 1962. Even though the median might be considered as a better estimate of central values, similar conclusions regarding the general rise in strontium levels in bone in 1963 over those found in the corresponding age groups in 1962 deaths might be drawn from the mean values given in figure 4. In both figures the most prominent changes are seen in the youngest age groups.

Inspection of table 2 and the corresponding table in a previous report (*4*) indicates that the median values for the 0–4 age group would be even higher if neonatal deaths (birth to one month) were excluded. There is good reason, in fact, to consider separately those cases in which death occurs in the first few months of

TABLE 1.—SUMMARY OF STRONTIUM-90 IN HUMAN BONE IN SELECTED DEATHS OCCURRING IN THE UNITED STATES IN 1962 AND 1963, BY YEAR OF DEATH, AGE AND GEOGRAPHIC ORIGIN. This table incorporates data for all individual cases from whom one or more bone specimens were analyzed in the Strontium-90 in Human Bone Program through June 1964. The "maximum" and "minimum" for each category are the highest and lowest values found in analysis of specimens from individual cases in the category. For comment regarding the average values, in view of the non-normal distribution in strontium units (Figures 1 and 2), see text.

[pc Sr^{90}/g calcium]

1962 DEATHS

Region	0-4 yrs.				5-9 yrs.				10-14 yrs.				15-19 yrs.				20-24 yrs				Total No.
	Mean	Min	Max	No.	Mean	Min	Max	No.	Mean	Min	Max	No.	Mean	Min	Max	No.	Mean	Min	Max	No.	
Northeast	4.8	1.6	9.7	9	5.1	2.4	9.4	7	2.8	1.8	4.7	7	2.7	1.1	4.6	8	2.1	1.3	4.9	12	43
Southeast	5.8	5.2	6.3	2	3.4	3.4	3.4	1	2.5	2.0	3.0	2	2.5	1.9	3.0	4	1.9	1.4	2.2	6	15
Central	2.6	0.8	7.2	34	2.1	1.3	2.7	22	2.1	0.8	3.5	13	2.0	1.2	3.4	12	1.8	0.9	2.8	8	89
Delta																	1.8	1.8	1.8	1	1
Northwest	2.9	2.9	2.9	1					2.1	1.8	2.6	3	1.8	1.3	2.4	4	1.7	1.4	2.4	3	11
Southwest	4.9	3.0	6.8	2	1.7	1.7	1.7	1	2.0	2.0	2.0	1	2.0	1.0	3.0	2	0.9	0.9	0.9	1	7
All	3.2	0.8	9.7	48	2.8	1.3	9.4	31	2.3	0.8	4.7	26	2.2	1.0	4.6	30	1.9	0.9	4.9	31	166

1963 DEATHS

Region	0-4 yrs.				5-9 yrs.				10-14 yrs.				15-19 yrs.				20-24 yrs.				Total No.
	Mean	Min	Max	No.	Mean	Min	Max	No.	Mean	Min	Max	No.	Mean	Min	Max	No.	Mean	Min	Max	No.	
Northeast	6.9	1.2	13.0	13	4.6	2.8	9.1	20	3.8	1.4	9.0	14	2.9	1.6	4.8	30	2.4	1.6	3.7	17	94
Southeast	1.9	1.9	1.9	1					2.0	2.0	2.0	1	3.6	3.3	3.9	2	1.9	1.5	2.4	4	8
Central	3.3	2.3	6.8	14	2.8	1.8	4.2	3	2.3	1.7	3.6	12	1.8	1.0	2.7	5	5.0	5.0	5.0	1	35
Delta					4.2	4.2	4.2	1	2.9	2.9	2.9	1	4.4	2.5	7.0	4	2.5	1.8	3.3	4	10
Northwest	4.1	3.5	4.7	2	2.4	2.2	2.6	2	3.8	1.8	5.9	2									6
Southwest					3.8	3.8	3.8	1	2.8	2.8	2.8	1	1.6	1.6	1.6	1					3
All	4.7	1.2	13.0	30	4.2	1.8	9.1	27	3.1	1.4	9.0	31	2.9	1.0	7.0	42	2.4	1.5	5.0	26	156

life because of the discrimination between strontium and calcium by the mother in absorption, excretion, and transplacental passage as well as for reason of diets frequently lower in strontium units during the first few months after birth.

These factors would be expected to manifest themselves by relatively lower strontium units in bone during the first few months of life and would subsequently be offset by accumulation of relatively higher radiostrontium levels from dietary sources in the absence of the maternal discrimination. That this effect is marked and prolonged during the first few months of life is consistent with observations given in table 3. Following the rise to relatively higher levels after the first months of life, there is a gradual decrease in strontium units in bone with increasing age. The observed regression on age holds true not only for combined results on specimens obtained throughout the nation, but generally for the six geographic regions, both in 1962 and 1963, except in those cases in which the number of specimens was too small to permit any inferences to be drawn.

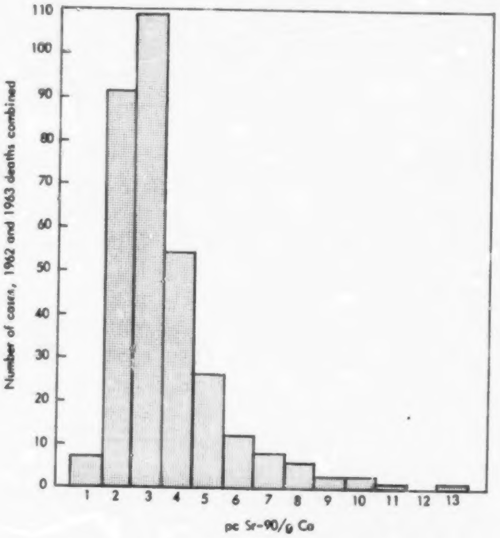

FIGURE 2.—FREQUENCY DISTRIBUTION FOR STRONTIUM UNITS (pc Sr^{90}/g Ca) IN HUMAN BONE FROM SELECTED U. S. DEATHS IN 1962 AND 1963. The distribution is skewed. The data include results for all individual cases for which specimens were analyzed in the strontium-90 in human bone program through June 1964.

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TABLE 2.—DETAILED DATA FOR INDIVIDUAL CASES, BONE SPECIMENS AND STRONTIUM-90 ANALYTICAL RESULTS. The table includes data for all individual cases for which analyses of strontium-90 content in bone were performed in the Strontium-90 in Human Bone Program in the interval from November 1963 through June 1964.

Region, State, and sample	Age at death	Sex	Date of death	Bone [a]	Original wt (g)	Ash wt (g)	pc Sr^{90}/g of— Ash	pc Sr^{90}/g of— Ca	pc Sr^{90}/g of— Bone	2σ counting error (%)
Northeast										
Conn.										
I-16(0001)	5 y	M	Sep 63	V, R	80	11.3	1.1	2.8	0.13	9
I-16(0002)	20 y	M	Sep 63	V, I	97	13.5	1.2	3.2	0.16	20
I-16(0002)	2 y	M	Sep 63	V, I	97	13.5	1.4	3.7	0.19	17
I-16(0002)	2 y	M	Sep 63	V, I	97	13.5	1.5	4.2	0.22	17
I-16(0003)	9 y	M	Oct 63	V	128	10.2	1.5	4.1	0.12	13
I-16(0005)	7 y	M	Oct 63	V, I	278	22.9	1.6	4.3	0.13	6
I-16(0006)	24 y	F	Nov 63	V	88	13.6	1.2	3.2	0.19	11
I-16(0007)	6 y	M	Dec 63	V, R	106	10.8	1.6	4.4	0.16	11
Maine										
I-9(0002)	18 y	M	Aug 63	I	80	17.2	0.50	1.5	0.13	26
I-9(0002)	18 y	M	Aug 63	I	80	17.2	0.81	2.0	0.16	12
Mass.										
I-2(0007)	12 y	M	Jun 63	V	112	11.5	1.9	5.0	0.12	19
I-2(0010)	2 y	M	Jul 63	V	125	9.4	2.5	7.3	0.19	11
I-2(0011)	5 y	F	Jul 63	V	144	12.4	1.4	4.0	0.12	13
I-2(0013)	14 y	F	Jul 63	V	207	17.7	1.2	3.6	0.11	16
I-2(0016)	10 y	F	Jul 63	V	116	14.9	0.61	1.9	0.09	31
I-2(0016)	10 y	F	Jul 63	V	116	14.8	0.75	2.0	0.10	7
I-2(0018)	1 y	F	Jul 63	V	67	5.7	2.3	7.7	0.23	8
I-2(0019)	5 y	F	Jul 63	V	169	14.3	1.7	5.0	0.16	14
I-2(0019)	5 y	F	Jul 63	V	169	14.3	1.8	5.4	0.16	11
I-2(0022)	15 y	F	Aug 63	V	123	14.3	1.2	3.3	0.14	20
I-2(0025)	5 y	M	Aug 63	V	169	13.6	2.1	5.7	0.17	13
I-2(0026)	9 y	M	Aug 63	V	103	10.5	1.1	3.2	0.12	10
I-2(0028)	10 y	F	Sep 63	V, R	111	11.8	1.2	3.1	0.13	14
I-2(0035)	17 y	M	Sep 63	V	223	22.4	0.80	2.2	0.08	9
I-2(0035)	17 y	M	Sep 63	V	223	22.4	0.84	2.3	0.08	7
I-2(0036)	8 y	M	Sep 63	V	96	9.1	1.3	3.7	0.12	12
I-2(0037)	14 y	F	Oct 63	V	118	16.1	1.3	3.7	0.18	16
I-2(0039)	10 y	M	Oct 63	V	226	17.9	0.42	1.4	0.04	29
I-2(0040)	12 y	M	Oct 63	V	75	8.3	1.7	4.7	0.19	11
I-2(0041)	16 y	F	Oct 63	V	152	17.3	1.4	3.7	0.14	8
I-2(0041)	16 y	F	Oct 63	V	152	17.3	1.6	4.2	0.18	7
I-2(0041)	16 y	F	Oct 63	V	456	17.3	1.8	4.7	0.22	7
I-2(0042)	3 y	F	Oct 63	V	70	5.0	2.5	6.9	0.18	13
I-2(0043)	7 y	M	Oct 63	V	81	8.1	2.6	7.5	0.26	19
I-2(0043)	7 y	M	Oct 63	V	81	8.1	2.6	7.6	0.27	4
I-2(0044)	13 y	F	Oct 63	V	94	11.4	1.7	4.7	0.21	3
I-2(0045)	6 y	M	Oct 63	V	84	5.5	3.1	9.1	0.20	17
I-2(0046)	3 y	M	Oct 63	V	166	9.2	4.6	13.0	0.25	10
I-2(0048)	4 y	F	Nov 63	V	68	5.7	2.9	8.0	0.24	11
I-2(0049)	19 y	F	Nov 63	V	85	9.6	1.3	3.4	0.14	10
I-2(0050)	20 y	M	Nov 63	V	111	14.4	1.2	3.4	0.15	20
I-2(0050)	20 y	M	Nov 63	V	222	14.4	1.5	4.0	0.21	3
I-2(0051)	14 y	M	Nov 63	V	168	16.2	0.96	2.6	0.09	9
I-2(0052)	3 y	M	Nov 63	V	168	13.1	2.0	5.3	0.16	8
I-2(0052)	3 y	M	Nov 63	V	168	13.1	3.0	7.7	0.23	7
I-2(0053)	11 y	F	Nov 63	V	141	12.2	3.1	9.0	0.27	6
I-2(0055)	9 y	M	Dec 63	V	257	23.4	1.6	4.2	0.15	5
I-2(0056)	18 y	M	Dec 63	V	228	24.7	0.98	2.6	0.11	8
I-2(0057)	3 y	F	Dec 63	V	98	7.4	1.7	5.2	0.19	12
I-2(0057)	3 y	F	Dec 63	V	98	7.4	2.4	6.6	0.22	88
I-2(0058)	19 y	M	Dec 63	V	144	14.1	0.90	2.5	0.09	10
I-2(0060)	6 y	M	Dec 63	V	100	9.5	2.1	6.1	0.20	8
I-2(0061)	2 y	M	Dec 63	V	103	8.2	2.8	8.5	0.21	8
Pa.										
II-19(0017)	19 y	M	Dec 62	V	153	23.6	0.63	1.7	0.10	24
II-19(0020)	20 y	M	Feb 63	V	190	23.9	0.65	1.8	0.09	22
Vt.										
I-6(0021)	20 y	F	Jun 63	V	95	15.3	0.78	2.1	0.12	23
I-6(0021)	20 y	F	Jun 63	V	95	15.3	1.0	2.6	0.17	30
I-6(0023)	9 y	M	Jun 63	V	150	16.1	1.1	2.9	0.12	13
I-6(0027)	18 y	M	Aug 63	V	144	18.3	0.90	2.4	0.12	19
I-6(0027)	18 y	M	Aug 63	V	144	18.3	1.1	3.0	0.14	17
I-6(0029)	18 y	M	Sep 63	V	104	15.5	1.0	2.8	0.18	18
I-6(0029)	18 y	M	Sep 63	V	104	15.5	1.2	3.2	0.16	10
I-6(0032)	15 y	M	Dec 63	V	146	20.2	1.3	3.6	0.18	11
I-13(0001)	2 y	M	Jul 63	V	118	12.7	3.4	10.1	0.39	10
I-13(0001)	2 y	M	Jul 63	V	118	12.7	4.0	11.8	0.45	6
I-13(0002)	8 y	M	Aug 63	V	180	15.6	1.1	3.2	0.10	19
I-13(0003)	15 y	M	Sep 63	V	155	20.8	0.80	2.0	0.10	21
I-13(0003)	15 y	M	Sep 63	V	155	20.8	0.84	2.4	0.12	8
I-13(0004)	14 y	F	Nov 63	V	110	14.1	1.5	3.2	0.18	8
I-13(0004)	14 y	F	Nov 63	V	221	14.1	1.6	4.3	0.22	3
Southeast										
Fla.										
IV-4(0001)	16 y	M	Aug 63	V, R	177	18.6	1.2	3.3	0.13	8

TABLE 2.—Continued

Region, State, and sample	Age at death	Sex	Date of death	Bone [a]	Original wt (g)	Ash wt (g)	pc Sr^{90}/g of—			2σ counting error (%)
							Ash	Ca	Bone	
Central										
Mich.										
V-13(0005)	15 y	M	Nov 62	V	111	17.1	0.73	1.9	0.11	11
V-13(0015)	15 y	M	Nov 62	V	111	17.2	0.87	2.3	0.13	32
Minn.										
VI-6(0003)	21 y	M	Nov 62	V, S	252	32.7	0.36	0.93	0.05	25
VI-6(0005)	16 y	M	Dec 62	V	112	15.3	0.56	1.5	0.08	14
VI-6(0005)	16 y	M	Dec 62	V	112	14.5	0.91	2.4	0.11	25
Mo.										
VI-2(0029)	16 y	M	Jan 63	R	36	14.2	0.57	1.5	0.27	28
VI-2(0029)	16 y	M	Jan 63	R	36	14.2	0.72	1.8	0.23	31
Ohio										
V-16(0001)	20 y	M	Nov 62	V	80	12.8	0.79	2.1	0.13	25
V-16(0001)	20 y	M	Nov 62	V	80	12.9	1.3	3.5	0.21	20
V-16(0006)	19 y	M	Apr 63	V	147	21.6	0.34	0.96	0.05	44
V-17(0002)	18 y	M	Dec 62	V	131	20.1	0.43	1.2	0.07	33
V-17(0002)	18 y	M	Dec 62	V	131	20.2	0.57	1.6	0.09	25
V-17(0006)	8 y	M	Apr 63	V	162	17.4	0.86	2.3	0.09	21
V-19(0016)	5 y	M	Jan 62	V	274	24.9	0.83	2.3	0.08	8
V-19(0017)	2 y	M	Jan 62	V	107	11.6	1.1	2.9	0.12	11
V-19(0019)	10 m, 17 d	M	Jan 62	V	212	21.6	0.70	1.9	0.07	10
V-19(0020)	8 y	M	Jan 62	V	182	14.3	0.47	1.3	0.04	17
V-19(0021)	11 y	F	Feb 62	V	258	23.4	0.29	0.78	0.03	17
V-19(0022)	1 y	M	Feb 62	V	272	26.4	0.65	1.8	0.06	6
V-19(0026)	2 d	F	Feb 62	V	125	12.5	0.33	0.90	0.03	21
V-19(0027)	8 y	M	Mar 62	V	314	19.3	0.46	1.4	0.03	15
V-19(0028)	12 y	M	Apr 62	V	414	19.4	0.81	2.2	0.07	11
V-19(0028)	12 y	M	Apr 62	V	207	19.4	0.81	2.4	0.08	10
V-19(0029)	2 y	M	Apr 62	V	140	9.5	0.79	2.3	0.05	16
V-19(0030)	6 m, 20 d	M	Apr 62	V	109	16.8	0.78	2.1	0.12	8
V-19(0031)	3 d	M	Apr 62	V	156	20.1	0.36	1.0	0.05	14
V-19(0031)	3 d	M	Apr 62	V	156	20.1	0.49	1.3	0.06	18
V-19(0032)	4 y	M	May 62	V	150	12.5	0.72	2.0	0.06	14
V-19(0033)	13 y	M	May 62	V	111	12.3	0.51	1.4	0.06	25
V-19(0037)	4 y	M	May 62	V	204	19.2	0.61	1.7	0.06	12
V-19(0038)	6 y	M	May 62	V	215	20.2	0.71	2.0	0.07	10
V-19(0040)	9 y	M	Jun 62	V	202	20.9	0.70	1.9	0.07	10
V-19(0041)	9 y	F	Jun 62	V	154	15.8	0.50	1.4	0.05	14
V-19(0042)	4 y	F	Jun 62	V	137	10.3	0.66	1.9	0.05	17
V-19(0043)	4 y	M	Jun 62	V	230	22.1	0.67	1.8	0.06	10
V-19(0045)	13 y	F	Jul 62	V	243	15.5	0.47	1.3	0.03	15
V-19(0045)	13 y	F	Jul 62	V	243	15.5	0.70	1.9	0.04	13
V-19(0046)	8 m	F	Jun 62	V	116	18.9	0.98	2.5	0.16	9
V-19(0047)	1 m, 29 d	M	Jul 62	V	96	12.2	0.63	1.7	0.08	14
V-19(0048)	11 m, 6 d	M	Jun 62	V	184	22.4	0.29	0.79	0.04	17
V-19(0049)	5 y	M	Jul 62	V	176	9.4	0.88	2.6	0.05	15
V-19(0050)	6 y	M	Aug 62	V	257	19.2	0.91	2.6	0.07	9
V-19(0051)	2 y	F	Jul 62	V	125	13.2	1.0	2.7	0.11	11
V-19(0052)	1 y, 6 m	M	Sep 62	V	170	19.3	1.3	3.7	0.15	8
V-19(0053)	4 y	M	Sep 62	V	234	24.3	1.1	3.1	0.12	8
V-19(0054)	3 y	M	Sep 62	V	132	9.6	1.1	3.1	0.08	12
V-19(0055)	9 y	M	Jul 62	V	188	18.4	0.54	1.5	0.05	28
V-19(0055)	9 y	M	Jul 62	V	188	18.5	0.88	2.5	0.09	10
V-19(0056)	7 m, 4 d	M	Sep 62	V	106	16.4	2.8	7.2	0.42	6
V-19(0058)	7 y	F	Oct 62	V	219	21.9	0.90	2.4	0.09	3
V-19(0059)	5 y	M	62	V	175	16.6	0.63	1.7	0.06	13
V-19(0059)	5 y	M	62	V	175	16.6	0.87	2.4	0.08	12
V-19(0060)	3 y	F	Sep 62	V	146	18.2	1.2	3.2	0.15	8
V-19(0061)	Stillborn	F	Aug 62	V	107	14.4	0.70	1.9	0.09	13
V-19(0062)	2 y	F	Sep 62	V	121	13.0	0.88	2.4	0.09	14
V-19(0064)	4 y	F	Nov 62	V	148	10.9	0.76	2.1	0.06	14
V-19(0065)	10 y	M	Oct 62	V	198	19.9	0.88	1.5	0.05	4
V-19(0065)	10 y	M	Oct 62	V	198	19.9	0.72	2.0	0.07	11
V-19(0066)	15 y	M	Oct 62	V	170	18.6	0.61	1.6	0.06	10
V-19(0066)	15 y	M	Oct 62	V	170	18.6	0.65	1.8	0.07	12
V-19(0066)	15 y	M	Oct 62	V	679	18.6	0.69	1.9	0.08	10
V-19(0067)	3 y	F	Nov 62	V	200	18.6	0.70	1.9	0.06	11
V-19(0068)	11 y	F	Oct 62	V	134	14.5	0.52	1.4	0.05	13
V-19(0068)	11 y	F	Oct 62	V	134	14.5	0.62	1.7	0.07	14
V-19(0069)	1 y, 7 m	M	Oct 62	V	129	14.8	0.98	2.7	0.11	10
V-19(0070)	5 y	M	Nov 62	V	183	14.8	0.93	2.6	0.08	6
V-19(0071)	2 y	F	Nov 62	V	103	9.3	1.92	5.2	0.17	10
V-19(0072)	13 y	F	Oct	V	148	17.4	0.65	1.7	0.08	12
V-19(0072)	13 y	F	Oct 62	V	148	17.4	0.65	1.8	0.08	12
V-19(0073)	1 y, 9 m	F	Nov 62	V	218	11.4	0.74	2.2	0.04	15
V-19(0074)	9 y	F	Oct 62	V	166	18.1	0.73	2.0	0.08	11
V-19(0074)	9 y	F	Oct 62	V	166	18.1	0.54	1.4	0.06	13
V-19(0075)	10 m, 11 d	M	Oct 62	V	103	10.5	1.7	4.5	0.17	10

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Table 2.—Continued

Region, State, and sample	Age at death	Sex	Date of death	Bone [a]	Original wt (g)	Ash wt (g)	pc Sr^{90}/g of— Ash	Ca	Bone	2σ counting error (%)
Central—Continued										
Ohio										
V-19(0076)	12 y	M	Aug 62	V	194	21.3	0.40	1.1	0.04	12
V-19(0076)	12 y	M	Aug 62	V	194	21.3	0.33	0.90	0.04	12
V-19(0079)	3 m, 13 d	M	Jan 63	V	100	8.4	1.2	3.4	0.10	14
V-19(0080)	5 y	M	Dec 62	V	164	16.3	0.82	2.2	0.08	11
V-19(0081)	9 y	F	Dec 62	V	226	20.9	0.86	2.3	0.08	9
V-19(0082)	9 y	M	Jan 63	V	248	18.5	0.64	1.8	0.05	12
V-19(0083)	3 y	F	Dec 62	V	110	8.8	1.2	3.3	0.09	13
V-19(0084)	11 y	M	Jan 63	V	177	12.8	0.64	1.8	0.07	16
V-19(0087)	6 y	F	Dec 62	V	187	20.9	0.85	2.3	0.09	11
V-19(0088)	1 y, 11 m	F	Dec 62	V	111	9.5	0.78	2.1	0.07	15
V-19(0090)	Stillborn	M	Dec 62	V	123	14.3	1.2	3.1	0.13	10
V-19(0091)	2 y	M	Dec 62	V	155	13.7	0.88	2.4	0.08	11
V-19(0092)	1 y, 2 m	F	Jan 63	V	107	12.2	0.93	2.5	0.11	13
V-19(0093)	4 y	M	Jan 63	V	117	10.3	1.4	3.9	0.12	14
V-19(0094)	5 m, 8 d	M	Dec 62	V	103	12.5	1.1	3.0	0.14	11
V-19(0095)	Stillborn	M	Jan 63	V	102	12.7	0.49	1.3	0.06	18
V-19(0096)	4 y	M	Jan 63	V	131	12.2	0.83	2.3	0.08	12
V-19(0098)	7 y	M	Nov 62	V	211	20.3	0.60	1.6	0.06	12
V-19(0099)	14 y	M	Feb 63	V	158	17.9	0.84	2.2	0.09	11
Wisc.										
V-3(0011)	10 y	F	Jan 63	V	214	22.4	0.76	2.0	0.08	17
V-3(0030)	4 y	M	Apr 63	V	56	4.7	1.8	6.8	0.19	14
V-3(0031)	4 y	M	Apr 63	V	144	13.5	1.2	3.3	0.11	19
Delta										
La.										
VII-8(0001)	25 y	M	May 63	V, R	158	24.3	0.81	2.1	0.12	10
VII-8(0008)	7 y	F	Aug 63	V, R	143	15.6	1.6	4.2	0.17	8
VII-8(0009)	15 y	M	Aug 63	V	98	16.7	1.8	4.7	0.30	8
VII-8(0011)	22 y	F	Sep 63	V	142	16.4	0.98	2.6	0.11	9
VII-8(0012)	20 y	F	Sep 63	V	162	22.0	1.2	3.3	0.17	7
VII-8(0016)	15 y	F	Nov 63	V	212	27.1	2.5	7.0	0.32	5
VII-8(0017)	22 y	M	Nov 63	V	139	20.6	0.89	2.3	0.13	10
VII-8(0017)	22 y	M	Nov 63	V	139	20.6	0.99	2.5	0.15	9
Miss.										
IV-6(0001)	13 y	M	Oct 63	V, R	152	25.9	1.2	2.9	0.20	8
Tenn.										
IV-9(0001)	20 y	F	May 63	V	89	15.5	0.72	1.8	0.12	12
IV-9(0002)	25 y	M	May 63	V	105	15.9	0.66	1.8	0.10	12
IV-9(0002)	25 y	M	May 63	V	105	15.9	0.81	2.1	0.12	12
IV-9(0006)	17 y	M	Aug 63	V	130	21.3	0.99	2.5	0.16	8
IV-9(0007)	18 y	F	Aug 63	V	141	22.0	1.3	3.4	0.20	7
Southwest										
Calif.										
IX-9(0008)	15 y	F	Nov 62	V	136	18.8	0.35	0.87	0.05	37
IX-9(0008)	15 y	F	Nov 62	V	136	18.8	0.39	1.1	0.05	36
IX-9(0008)	15 y	F	Nov 62	V	136	18.8	0.41	1.1	0.06	39
IX-9(0009)	13 y	F	Oct 62	V	133	19.7	0.46	1.2	0.06	30
IX-9(0009)	13 y	F	Oct 62	V	133	19.7	0.59	1.6	0.08	12
IX-9(0009)	13 y	F	Oct 62	V	133	19.7	1.2	3.1	0.20	14
Texas										
VII-1(0007)	11 y	M	Mar 63	V	227	25.5	1.1	2.8	0.12	8
VII-11(0001)	15 y	F	Surg 63	F	126	28.9	0.63	1.6	0.13	10
VII-11(0003)	5 y	M	Sept 63	V, R, I	115	12.3	1.3	3.8	0.25	8

[a] V, vertebra; R, rib; I, ilium; S, sternum; F, femur.

Table 3.—MEAN STRONTIUM UNITS IN HUMAN BONE IN SELECTED UNITED STATES DEATHS AT AGES UNDER ONE YEAR AND AT 1-4 YEARS, AND FOR BOTH GROUPS COMBINED. The data include all 1962 and 1963 deaths in the designated age groups for which bone specimens were analyzed in the Strontium-90 in Human Bone Program through June 1964.

Year in which death occurred	Mean strontium units in age group 0-12 months	1-4 years	0-4 years
1962	2.5	3.5	3.2
1963	2.2	5.0	4.7

Table 4.—STRONTIUM-90 SKELETAL CONCENTRATIONS CORRESPONDING TO FEDERAL RADIATION COUNCIL RANGES (4).

[pc Sr^{90}/g calcium]

FRC Range	Population "average"	Individuals
I	0-5	0-15
II	5-50	15-150
III	50-500	150-1500

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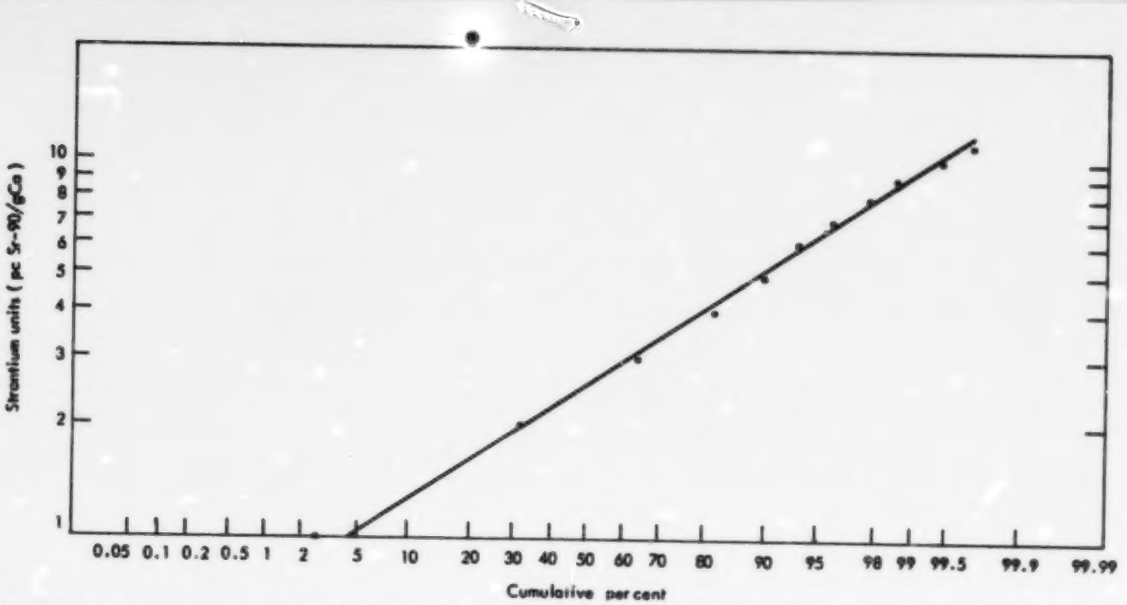

FIGURE 3.—PROBABILITY LOGARITHMIC PLOT OF STRONTIUM UNITS (pc Sr^{90}/g Ca) IN HUMAN BONE FROM SELECTED U.S. DEATHS IN 1962 AND 1963. The distribution is log-normal. The data include cumulative results for all individual cases for which specimens were analyzed in the strontium-90 in human bone program through June 1964.

While the results might, at first glance, appear to suggest that relatively higher strontium-90 bone levels have occurred in the Northeast than in other geographic areas, existing information does not permit adequate comparison of data from different geographic areas. For example, comparison of age-paired cases from the Northeast and the Central regions, which might be suggested by the relatively large numbers of specimens from these areas, is not feasible mainly for the reason that dates of death are not comparable.

Discussion

To investigate possible public health significance of data in this report it is of interest to compare these with strontium-90 skeletal concentrations which have been considered (*4*) to correspond to the three "ranges of transient rates of daily intake" cited by the Federal Radiation Council (*6*). The strontium-90 skeletal concentrations and the FRC intake "ranges" which have been related are listed for convenience in table 4. From bone data included in table 3 for two age groups, there is some suggestion that the skeletal concentration of strontium-90 considered to correspond to the upper limit of FRC Range I for the "population average" (table 4) was reached in 1963 for the 1–4 year age group (average value of 5 S.U.). The upper limit of the skeletal concentration related to FRC Range I for individuals was approached in one 1963 case; the value was 13 S.U. (table 1). However, it must be remembered that these data can only be absolutely related to the respective individual cases and not necessarily to a suitable sample of the exposed population.

Summary

Since late in 1961 the Public Health Service has conducted a program to provide estimates of strontium-90 levels in man. The authors analyzed data obtained through June 1964 in the Strontium-90 in Human Bone Program, and reported new analytical results, obtained from November 1963 through June 1964, for strontium-90 analyses of tissue from selected autopsies performed throughout the United States during 1962 and 1963. These were from cases less than 25 years old at death.

The distribution for strontium units (pc Sr^{90}/g Ca) in bone was log normal. Concentrations of strontium-90 in bone decreased with increasing age except during the first few months after birth. The latter observation is consistent with the well-known maternal discrimination against strontium in favor of calcium. This is believed to be principally responsible for the relatively low concentrations of strontium-90 in bone observed during the first few months after birth.

In the 1963 data, levels of strontium-90 in bone were higher than in individuals of similar ages who died in 1962. The observed average concentrations in 1963 in the 1–4 year age group correspond approximately to the upper limit of Range I of the guidance of the Federal Radiation Council (*6*). This guidance is used to provide some perspective of the strontium-90 burden even though the current FRC guidance does not indicate when protective action should be taken against fallout from nuclear weapons tests.

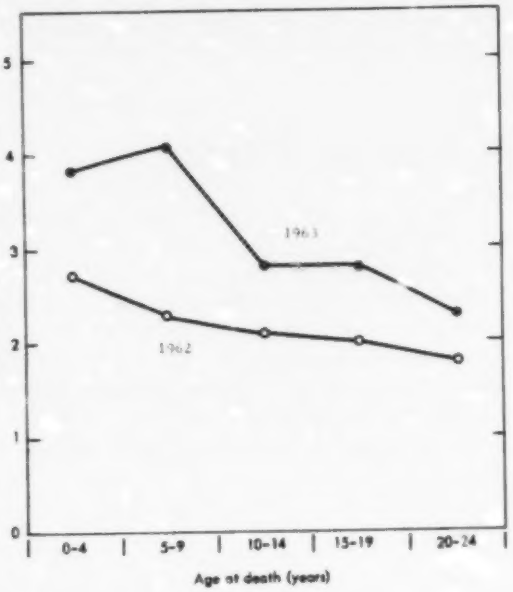

FIGURE 4.—MEAN STRONTIUM UNITS (pc Sr^{90}/g Ca) IN HUMAN BONE PLOTTED AGAINST AGE AT DEATH IN SELECTED U. S. DEATHS IN 1962 AND 1963. The data include all individual cases for which specimens were analyzed in the strontium-90 in human bone program through June 1964.

Vertical lines above and below the mean values represent one standard error of the mean in each direction. For comment regarding the average values and their standard errors, in view of non-normal distribution (figures 1 and 2), see text.

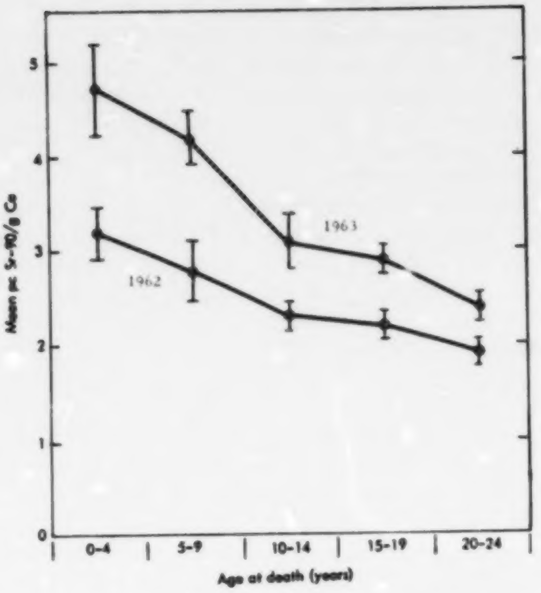

FIGURE 5.—MEDIAN STRONTIUM UNITS (pc Sr^{90}/g Ca) IN HUMAN BONE PLOTTED AGAINST AGE AT DEATH IN SELECTED U.S. DEATHS IN 1962 AND 1963. The data are based on the same analytical results as in figure 3.

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REPORTED NUCLEAR DETONATIONS, NOVEMBER 1964

During November 1964 one nuclear test was announced by the Atomic Energy Commission. This was an underground nuclear experiment conducted on November 5, at the Nevada Test Site as part of the Plowshare Program for peaceful uses of nuclear explosives.

The yield of this test was about 10 kilotons. It has been assigned the arbitrary *RHD* reference number 172.

Correction for Reported Nuclear Detonations, October 1964

In last month's summary of Reported Nuclear Detonations, *RHD* omitted a test conducted October 9 at the Nevada Test Site. This underground experiment, with a yield of about 30 kilotons, was part of the Plowshare Program.

The corrected chronological *RHD* reference numbers listed for October are, therefore, 167 through 171.

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